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TOPEX Radar Altimeter Engineering Assessment Report Update - Side B Turn-On to January 1, 2000

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Foreword

The Engineering Assessment of the TOPEX Radar Altimeter is performed on a continuing basis by the TOPEX Altimeter Team at NASA / GSFC Wallops Flight Facility. The Assessment Team members are:

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For the latest updates on the performance of the TOPEX Radar Altimeter, and for accessing many of our reports, readers are encouraged to contact our WFF / TOPEX Home Page at http: / / topex.wff.nasa.gov.

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Section 1
Introduction

1.1 Identification of Document

The initial TOPEX Radar Altimeter Engineering Assessment Report, in February 1994, presented performance results for the NASA Radar Altimeter on the TOPEX/POSEIDON spacecraft, from the time of its launch in August 1992 to February 1994.

Since that initial report and prior to this report, there have been five interim supplemental Engineering Assessment Reports, issued in March 1995, May 1996, March 1997, June 1998, and again in August 1999. The 1995-1998 reports updated the performance results to the end of calendar years 1994, 1995, 1996, and 1997, respectively. The 1999 report updated the performance to the time that TOPEX Side-A was turned off, on February 10, 1999. Side B was turned on the following day, marking the first time that Side B had been turned on since prior to launch.

This sixth supplement is the first assessment report that addresses Side-B performance, and presents the altimeter performance from the turn-on of Side-B until the end of calendar year 1999.

As the performance data base has expanded, and as analysis tools and techniques continue to evolve, the longer-term trends of the altimeter data have become more apparent. The updated findings are presented here.

Section 2

On-Orbit Instrument Performance

From the time of the initial turn-on of Side B on February 10, 1999, to the end of 1999, the NASA Radar Altimeter has been in TRACK mode for a total of approximately 7,000 hours. The altimeter had been in IDLE mode for an additional 700 hours, generally due to the French Altimeter's being turned on. The altimeter has been OFF for a total of 24 hours, due to a 16-hour spacecraft-level safehold on August 31, 1999, and to a related eight-hour OFF status three days later to switch the spacecraft attitude control electronics.

The succeeding sub-sections discuss:

- transition from Side A to Side B
- matching Side B science data to Side A
- launch-to-date internal calibration results
- launch-to-date cycle summary results
- launch-to-date key events
- land-to-water acquisition times

2.1 Transition to Side B

Side B of the NASA Radar Altimeter was turned-on for the first time in orbit on February 10, 1999. Side A had been turned off the previous day. The transition from Side A to B followed several weeks of careful planning / reviewing of command sequences.

The summarized turn-on / check-out sequence was as follows:

- February 10 - Commanded Side B to IDLE mode and uploaded the memory patches which had been implemented for Side A. The only observed concern was that the DCG Gate Array temperature was about 30 degrees (Centigrade) higher than expected, based on prelaunch testing results. All other engineering data were at- or near-specification. [The DCG Gate Array has remained at that elevated temperature without any apparent harm to the altimeter or its data.]
- February 11 - Commanded Side B to STANDBY and then to TRACK mode. The altimeter's tracking performance and its internal calibrations were nominally excellent. Performed baseline tests, including Mode Checks, Cal-Sweep, and Waveform Leakage.
- February 12 - Performed additional baseline tests, including Cal-Sweep, Waveform Leakage, and Gate-Shifts.Collected and analyzed additional normal-mode tracking data. A significant difference between Sides A and B is that

the Side B waveforms do not have leakages which were clearly evident in Side A.

- February 13-16 - Collected and analyzed normal-mode tracking data.
- February 17 - Performed Gate-Shift tests. Collected and analyzed additional normal-mode tracking data.
- February 18 - Performed Cal-Sweep test. Collected and analyzed additional normal-mode tracking data.
- February 19 - Performed Off-Nadir tracking tests.
- February 20 - Began the first Side B operational cycle [Cycle 237]. Some small-angle (0.15 and 0.10 degree) Off-Nadir testing continued into the early part of the operational Cycle 237 data.

2.2 Matching Side B Science Data to Side A

After approximately 60 days of operational Side B data had been collected and analyzed, minor data corrections were adopted to match Side B science data to Side A science data (prior to Side A's PTR change).

The Side B Cal / Val Meeting #1 was held at GSFC / Greenbelt on April 22, 1999. The summary results from the meeting were documented in an April 30, 2000, e-mail message disseminated by Phil Callahan, the TOPEX Measurement System Engineer. The main points of his message follow:

1. Alt-B is performing very well. Engineering personnel (WFF) are not particularly concerned about the high temperature of the chip in the chirp generator.

2. Offsets

- ***Sea Surface Height:*** *There is approximately a 20 mm offset of SSH with Alt-B measuring longer than Alt-A, so SSH is lower. This will be adjusted after the other changes below are incorporated.*
- ***Pointing Angle/Sea State Correction:*** *Waveform processing indicates that Alt-B corrections need to be adjusted by a few mm (differs by gate) and to have some additional SWH dependence corrected to make them the same as Alt-A. Waveform processing also shows that the K and C band PA/SS corrections move apart at SWH >~ 4 m which will cause the dual frequency ionosphere to change.*
- ***Ionosphere:*** *Even with the current offset of 120 mm in C band to adjust the ionosphere, the Alt-B dual frequency ionosphere is too small compared to Alt-A by about 6 mm.*
- ***Sigma0:*** *Current K band sigma0 offset of 0.5 dB is OK. Current C band offset of 0.6 dB appears to be too high; reduce to 0.5 dB.*
- ***SWH:*** *Current NO offset is OK.*
- ***Flagging:*** *No flagging changes were identified.*

As a follow-up to the above summary e-mail, the changes to Side B to match Side A were implemented in the subsequent few weeks. As part of the implementation, the C-band range offset was adjusted to give a 6 mm change in iono, and the Ku-band range offset was adjusted to result in a net 20 mm shorter range. These range offsets and the sigma0 offsets are controlled by the parameters file SPA_ALT_CALPAR.TXT in the JPL ground data processing. The parameters file change was specified by MOS Change Request (MCR) Number 690 dated 05/26/99.

Side B does not have the waveform leakage signals which were present in Side A, so the waveform addition factors in Algorithm T5135 were set to zero for Side B. The waveform gain factors in T5135 were left unchanged from Side A. The principal job of the gain factors is to correct for the "sawtooth" effect in the digital filter bank which arose from a truncation instead of a roundoff in one of the stages of the FFT as implemented in the TOPEX digital hardware.

Based on early Side B waveform fitting results and analysis by Ernesto Rodriguez and Phil Callahan at JPL, the Side B Pointing Angle/Seastate corrections were adjusted relative to the Side A corrections by the amounts given in Table 2-1.

Table 2-1 Pointing Angle/Seastate Algorithm S1037 Side B Range Adjustments Relative to Side A, in Millimeters

Gate Index	Ku-band Adjustment	C-band Adjustment
1	+1	-2
2	+5	+1
3	+9	+2
4	+16	-4
5	+20	-4

Except for the several adjustments described in this section, all the other ground software parameters were left the same in Side B as in Side A. The final set of ground processing coefficients was installed in the JPL software, also specified by MCR 690, and the reprocessing of Side B from the beginning of Cycle 236 was accomplished.

2.3 Launch-to-Date Internal Calibrations

The TOPEX altimeter's internal calibration mode has two submodes designated CAL-1 and CAL-2. In CAL-1 a portion of the transmitter output is fed back to the receiver through a digitally controlled calibration attenuator and delay line. The altimeter acquires and tracks this calibration signal for 10 seconds at each of 17 different preset calibration attenuator values; each calibration attenuator value is changed by 2 dB from its neighbor. The altimeter's CAL-1 has almost the same signal path as the normal fine-track mode, except that CAL-1 has a delay line, a different attenuator, and switches to select these components. The altimeter's automatic gain control (AGC) loop is active during each CAL-1 step, so changes in CAL-1 range and AGC should be directly relatable to changes in the altimeter's fine-track range and power estimation. The AGC level of CAL-1 Step 5 best represents the average level seen in normal over-ocean fine-tracking, so CAL-1 Step 5 data are used in the Section 3 discussions of changes in range and power estimation.

When commanded to its calibration mode, the TOPEX altimeter first enters CAL-1 and then CAL-2. Each of the 17 steps within CAL-1 lasts about 10 seconds, and then CAL-2 lasts about a minute, so the entire calibration sequence lasts about 4 minutes. Internal altimeter calibrations are scheduled twice-per-day, over land areas, at approximately 0000 UTC and 1200 UTC. Internal calibrations are also performed whenever the NASA altimeter is commanded from TRACK to IDLE for a period of tracking by the French altimeter, or from IDLE back to TRACK when tracking resumes for the NASA altimeter. The calibrations prior to and after the French altimeter operations are not constrained to land areas, and usually occur over open ocean.

Our processing of the CAL-1 range data was modified in 1994, to remove the effect of the 7.3 mm quantization; the revised method is discussed in Section 2.1.1 (page 2) of the March 1995 supplement. All the calibration data since launch have been processed using the revised method.

In the launch-to-date calibration plots which follow, the switchover from Side A to Side B begins at elapsed day 2,358 from 1992239; data step functions are generally apparent at the time of the switchover. The prior Side A data are included in the plots to illustrate the similarities or differences between Side A and Side B.

2.3.1 Range Calibrations

The change in Ku-Band range, from day 239 of 1992 to the end of 1999, is plotted in Figure 2-1 "Ku-Band Range CAL-1 Results" on page 2-5.

CAL-1 steps 4 through 7 are shown in the figure. Step 5 best represents typical AGC levels for normal ocean fine-track operation, and has been used for the range trend analysis presented in Section 3.1

The Ku-Band delta range shown in Figure 2-1 (and in the succeeding calibration plots) is calculated based on the measurement minus a reference. This calibration range plot indicates that the Side B Ku-Band delta range has varied only about +1 mm from the time of its turn-on to the end of 1999.

The change in C-Band calibration range is depicted in Figure 2-2 "C-Band Range CAL-1 Results" on page 2-6. This plot indicates that, since turn-on, the Side B C-Band range has negatively drifted (i.e., become shorter) by about 5 mm. As shown in the figure, the Side A C-Band had a similar drift when it was initially turned on in 1992. One observable difference is that the Side B C-Band range calibration data is more noisy than Side A data was during its first year in operation. Range calibrations and their correction values are discussed in more detail in Section 3.1.

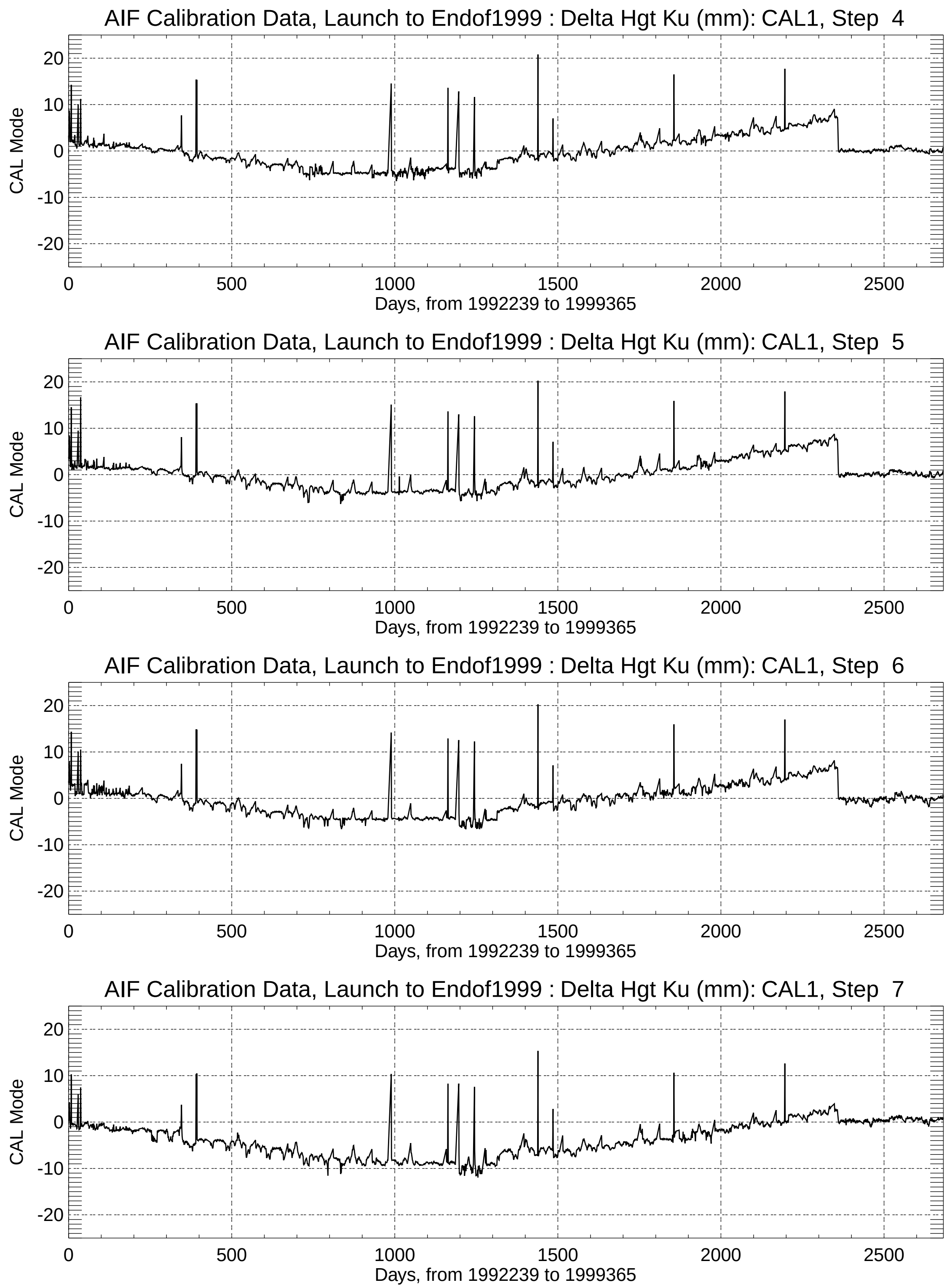

Figure 2-1 Ku-Band Range CAL-1 Results

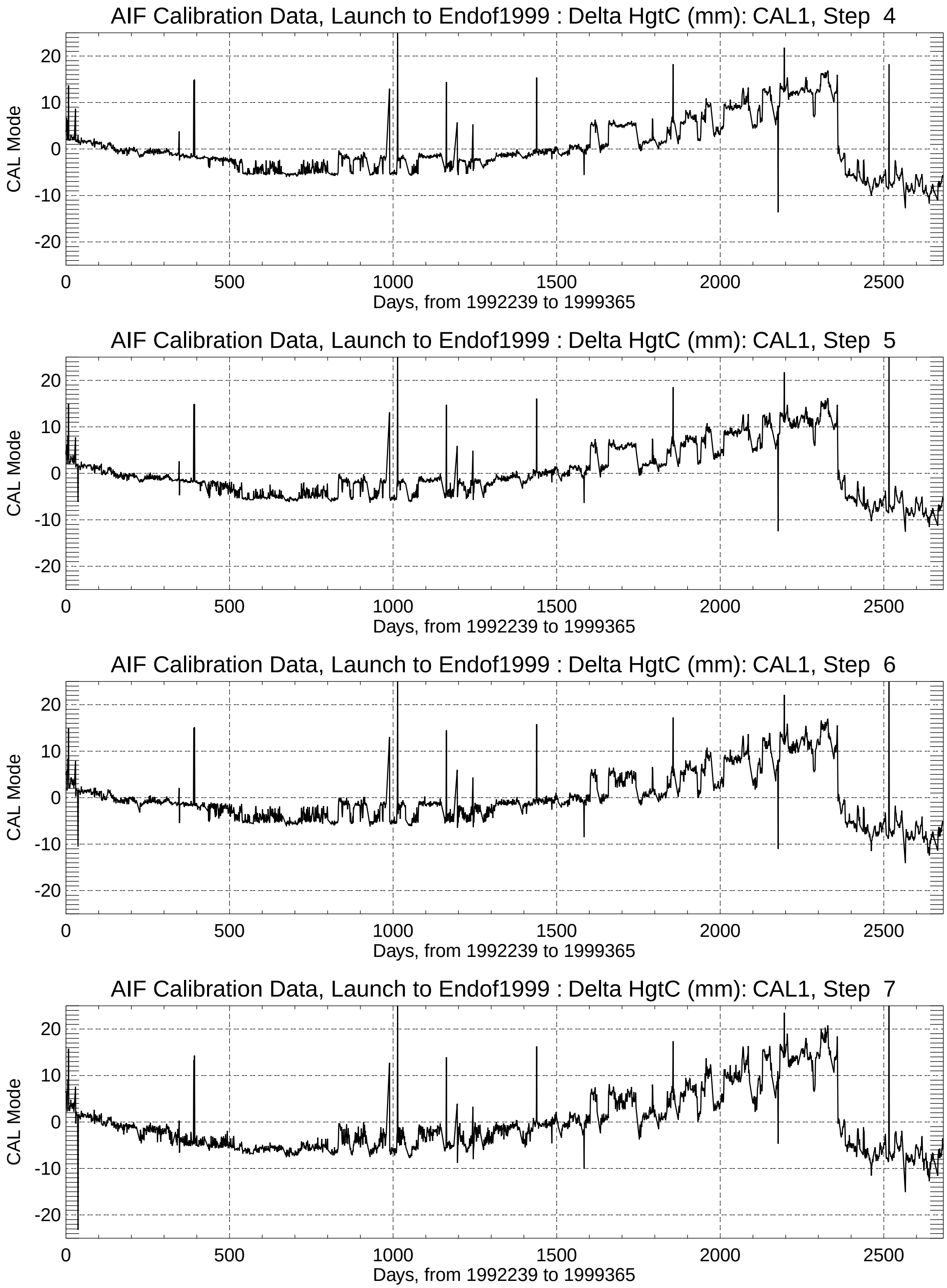

Figure 2-2 C-Band Range CAL-1 Results

2.3.2 AGC Calibrations

2.3.2.1 CAL-1 and CAL-2

The change in Side B Ku-Band AGC since launch is shown in Figure 2-3 "Ku-Band AGC CAL-1 and CAL-2" on page 2-8. CAL-1 steps 4 through 6, plus CAL-2, are depicted in the figure. As for the earlier range calibration, Step 5 of the CAL-1 AGC steps is considered to be the most typical for normal ocean operations. From the time of Side B turn-on, on elapsed day 2358, the Ku-Band AGC has apparently increased by approximately 0.3 dB. Most of this increase occurred right after the Safehold (elapsed day 2560 in the figure). Such an increase is quite different from Side A which experienced AGC decreases throughout its on-orbit period. Further, this sudden AGC increase appears to have changed the altimeter's acquisition characteristics; this acquisition change is discussed later in Section 2.6.

The change in C-Band AGC since Side B turn-on is shown on the right side of Figure 2-4 "C-Band AGC CAL-1 and CAl-2 Results" on page 2-9. The Side B AGC has remained at essentially the same level ($\pm$0.1 dB) since turn-on, similar to the early days of Side A. A more thorough analysis of the AGC calibrations is presented in Section 3.2.

2.4 Launch-to-Date Cycle Summaries

The data in the launch-to-date cycle summary plots which follow are extracted from the Geophysical Data Record (GDR) database at WFF. The criteria for TOPEX GDR measurements to be accepted for the WFF database are: 1) the data are classified as Deep Water, 2) the data are in normal Track Mode, and 3) selected data quality flags are not set.

For each measurement type, the plots contain one averaged measurement per cycle. The cycle average value is itself the mean of one-minute along-track boxcar averages, after editing. Data are excluded from the averaging process whenever the one-minute-averaged off-nadir angle exceeds 0.12 degree or the averaged Ku-Band sigma-naught exceeds 16 dB or whenever the number of non-flagged frames within the one-minute interval is fewer than 45. These edit criteria primarily have to do with eliminating the effects of sigma-naught blooms. As a result of this edit, approximately 15% of the database measurements are excluded from the averaging process. This tight editing is part of our effort to ensure that anomalous data are excluded from the performance assessment process.

2.4.1 Sea Surface Height

The sea surface heights (ssh) contained in the GDR files are based on combined heights. Cycle-average ssh are shown in Figure 2-5 "Cycle-Average Sea Surface Heights in Meters" on page 2-10. It is not possible to discern range drifts at the millimeter level from these data, but seasonal variations of sea level are observable.

Beginning with cycle 17, ssh has a 36.8-day-cycle periodicity. For example, lower ssh levels during cycles 25 through 35 are echoed during cycles 62 through 72, again during cycles 99 through 109, during cycles 135 through 145, during cycles 172 through

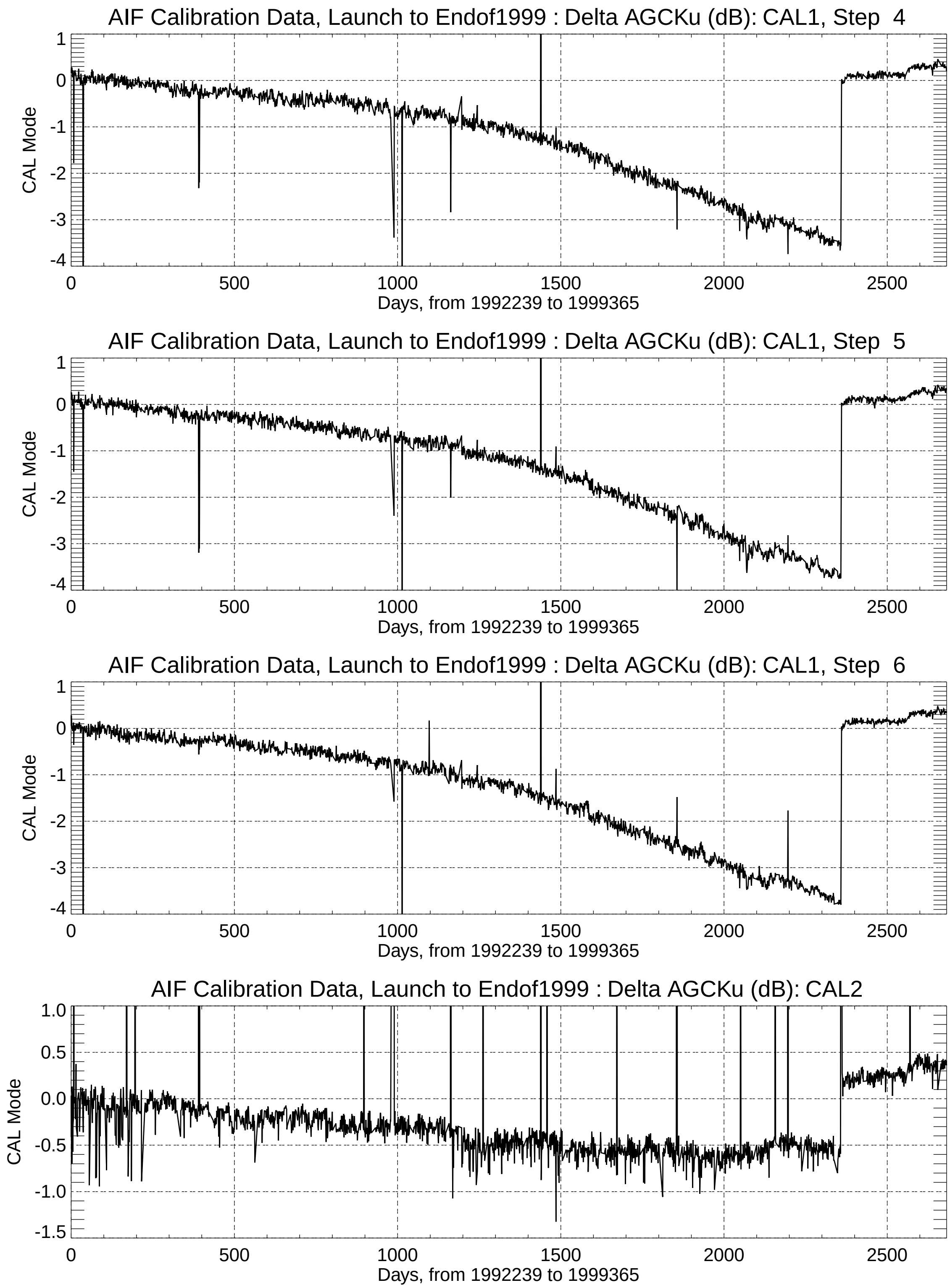

Figure 2-3 Ku-Band AGC CAL-1 and CAL-2

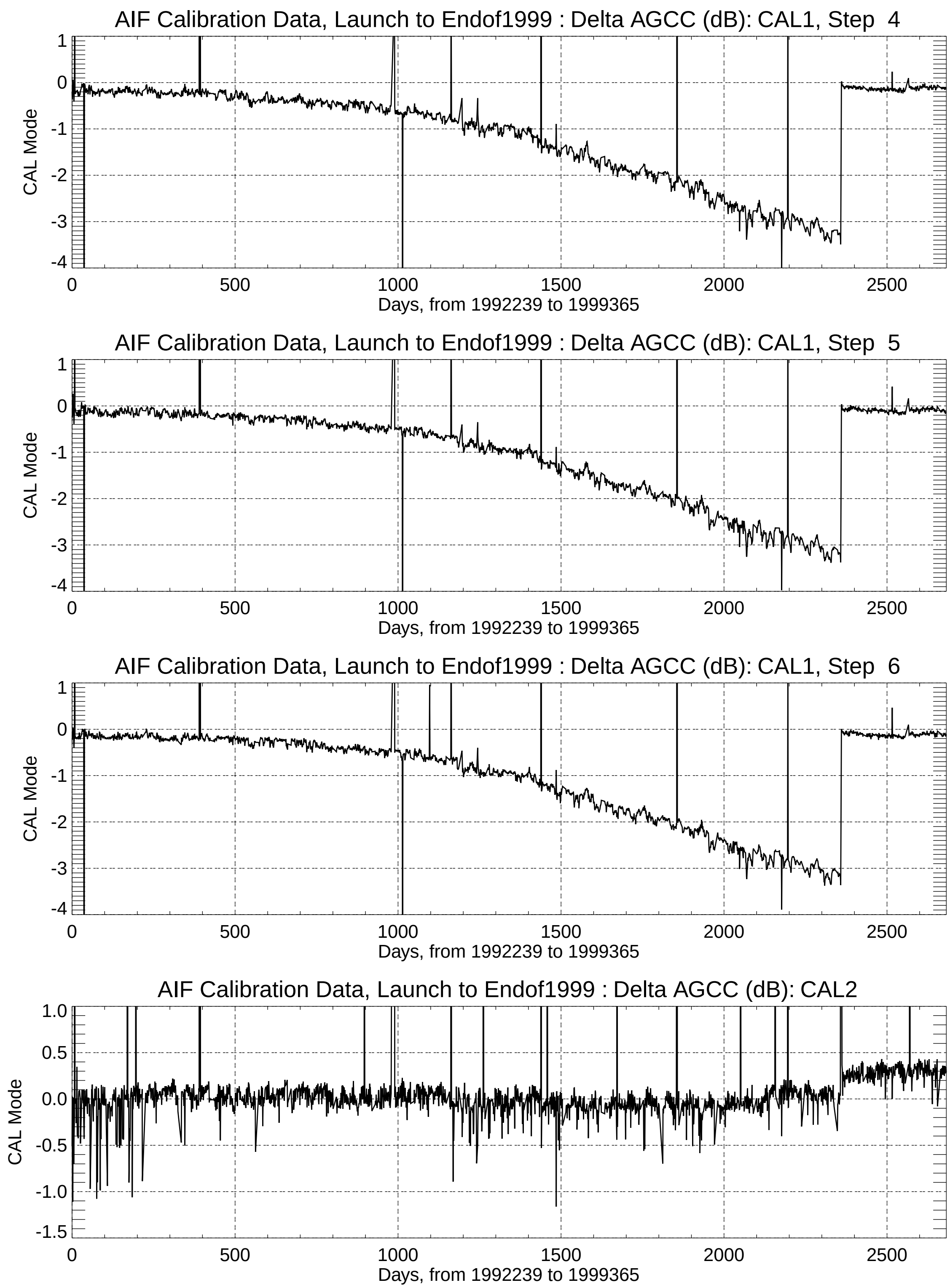

Figure 2-4 C-Band AGC CAL-1 and CAl-2 Results

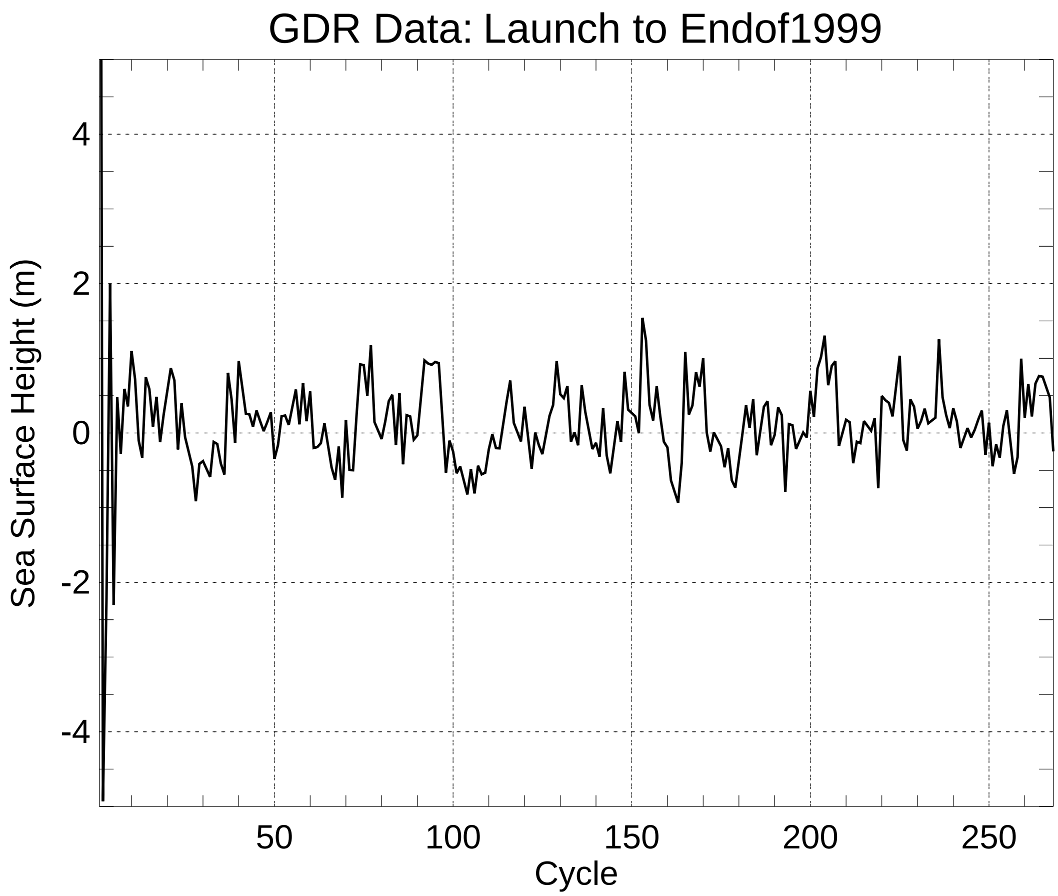

Figure 2-5 Cycle-Average Sea Surface Heights in Meters

182, during cycles 209 through 219, and again during cycles 246 through 256. Higher ssh levels are observed during cycles 37 through 43, during cycles 74 through 80, during cycles 110 through 116, during cycles 147 through 153, cycles 184 through 190, and again during cycles 221 through 227. Repeatability is not expected prior to Cycle 17 because, prior to this, the NASA altimeter was not in TRACK mode for full cycles. This expected periodicity, along with the fact that the periodicity continues through the change of altimeter sides (at the beginning of Cycle 236) lends credence that the Side A/B altimeter data remain internally consistent.

2.4.2 Sigma-Naught

The sigma-naught cycle-averages, after adding the non-temperature-corrected sigma-naught corrections, are plotted in Figure 2-6 "Cycle-Average Ku-Band Sigma-naught in dB" on page 2-11 and Figure 2-7 "Cycle-Average C-Band Sigma-naught in dB" on page 2-12, for Ku-Band and C-Band, respectively.

From cycle 17 to the present, Ku-Band sigma-naught cycle-averages, after correction, have generally remained within a window of 11.10±0.20 dB, and C-Band sigma-naught cycle-averages have generally remained at 14.70±0.20 dB. There are apparent annual cycles in the sigma-naught averages, particularly in the Ku-Band (low values

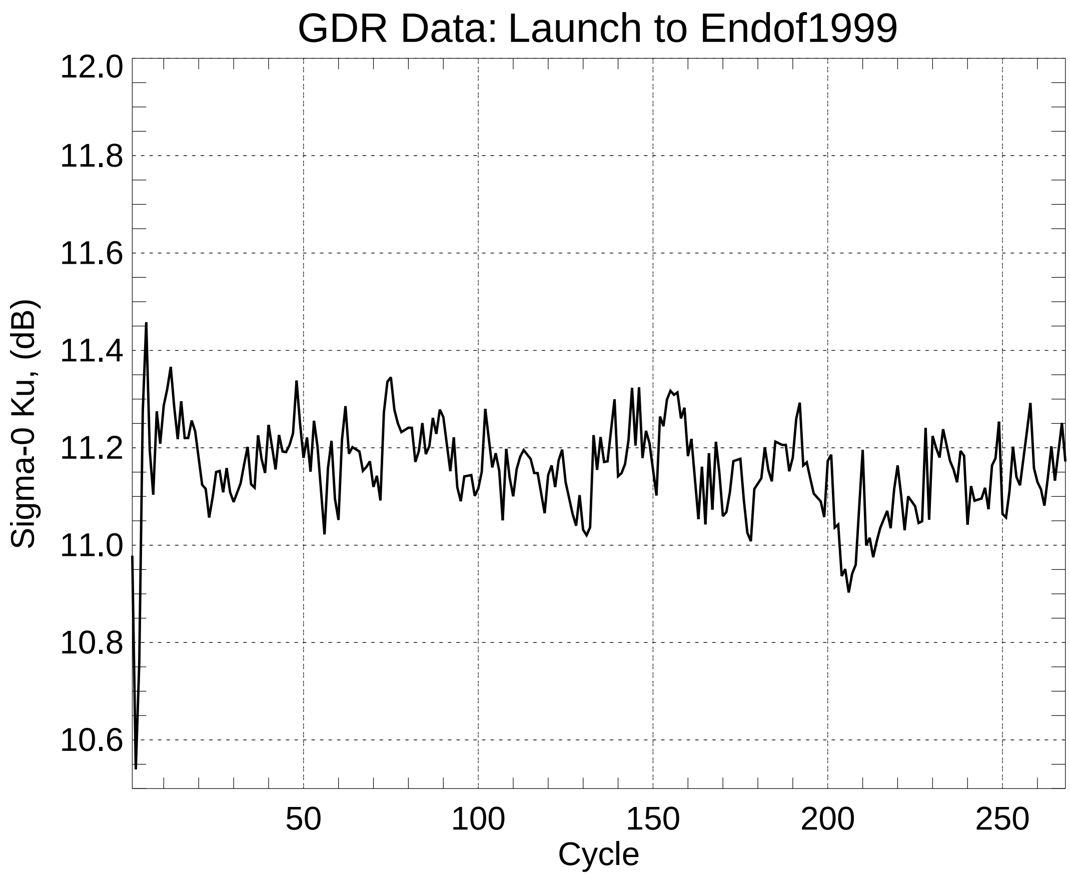

Figure 2-6 Cycle-Average Ku-Band Sigma-naught in dB

occur at cycles 22, 59, 96, 132, 169, 206 and 243 (Side B)). Even with the annual effects and with the switchover to Side B, the sigma-naughts have remained internally consistent and within the pre-launch design goal for sigma-naught accuracy of $\pm$0.25 dB.

2.4.3 Significant Wave Height

Ku-Band cycle-averages for significant wave height (swh) are shown in Figure 2-8 "Cycle-Average Ku-Band Significant Wave Height in Meters" on page 2-13. Subsequent to cycle 8, and prior to cycle 190, the cycle-average swh's remained in the range of 2.8+0.3 m, with no obvious long-term drift. However, beginning with cycle 190, the swh are observed to be anomalously high.

Upon the appearance of the anomalously high swh's, we consulted members of the TOPEX Science Team to discern whether the observed values might be real or might be due to an instrument effect. After a study, the cause was attributed to an instrument effect; this finding led to the decision to switch the Altimeter from Side A to Side B in February 1999. These high values are attributed to a change in the altimeter's Point Target Response (PTR); these effects are discussed further in Section 3.3.

Prior to Cycle 190, when the swh anomaly appeared, there is an annual cycle in the data, with particularly low swh's (2.5-2.6 m) centered around cycles 11, 48, 85, 122,

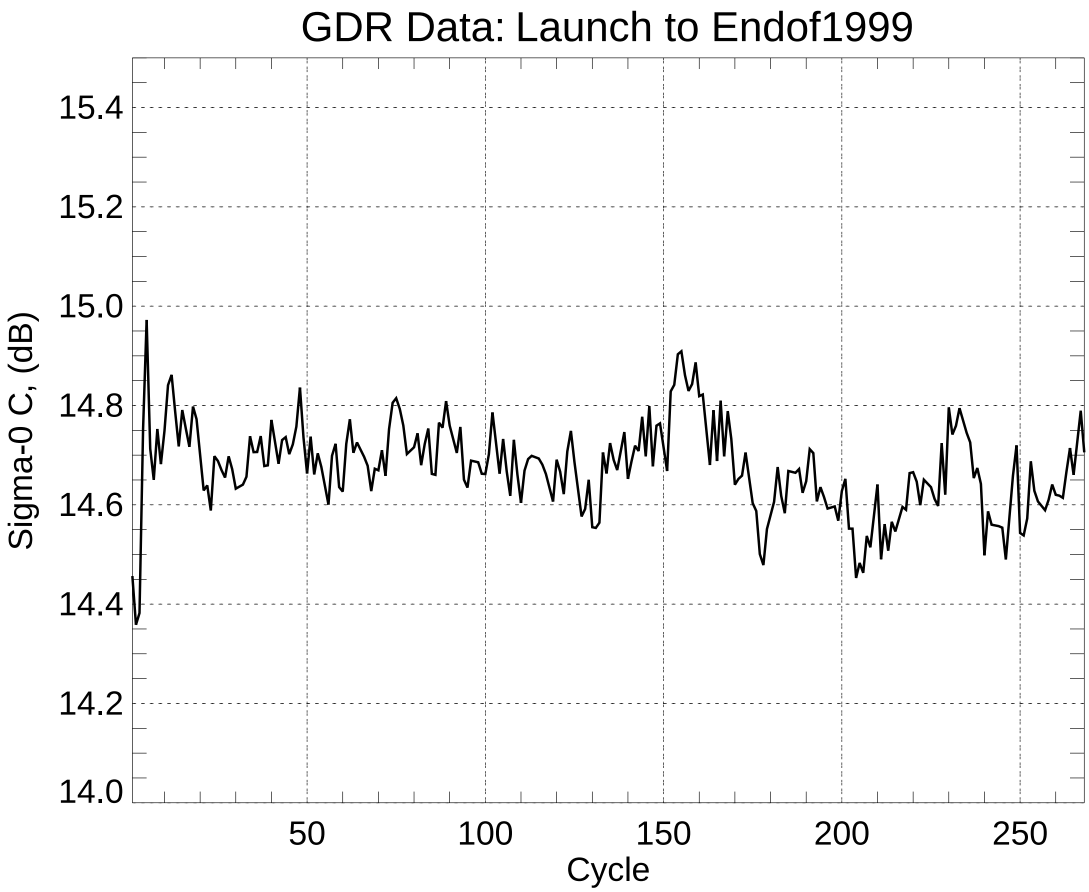

Figure 2-7 Cycle-Average C-Band Sigma-naught in dB

and 159, gradually building up to 3.0-3.1 m swh centered around cycles 23, 60, 97, 134, and 171. Cycles 11, 48, 85, 122, and 159 occurred in early January 1993, January 1994, January 1995, January 1996 and January 1997, respectively, corresponding to summer in the southern hemisphere. Cycles 23, 60, 97, 134, and 171were in early May 1993, May 1994, May 1995, May 1996, and May 1997 respectively, corresponding with early fall in the southern hemisphere. The southern hemisphere is referred to here because there is a considerably higher percentage of the total ocean area south of the equator.

Subsequent to the switch to Side B (Cycle 236), the pre-Cycle-190 SWH annual cycles have reappeared, lending more credence to Side A / Side B data consistency.

2.4.4 Range RMS

The calculated Ku-Band range rms values depicted in Figure 2-9 "Cycle-Average Ku-Band Range RMS in Millimeters" on page 2-14 are based on the rms derivation described in Section 5.1.1 of the February 1994 Engineering Assessment Report. Subsequent to cycle 17, and prior to cycle 165 (March 1997), the rms values remained in a narrow band of 18.5$\pm$0.9 mm, and are observed to be directly correlated with the swh's in Figure 2-8; the higher the SWH, the higher the rms. Beginning with cycle 165

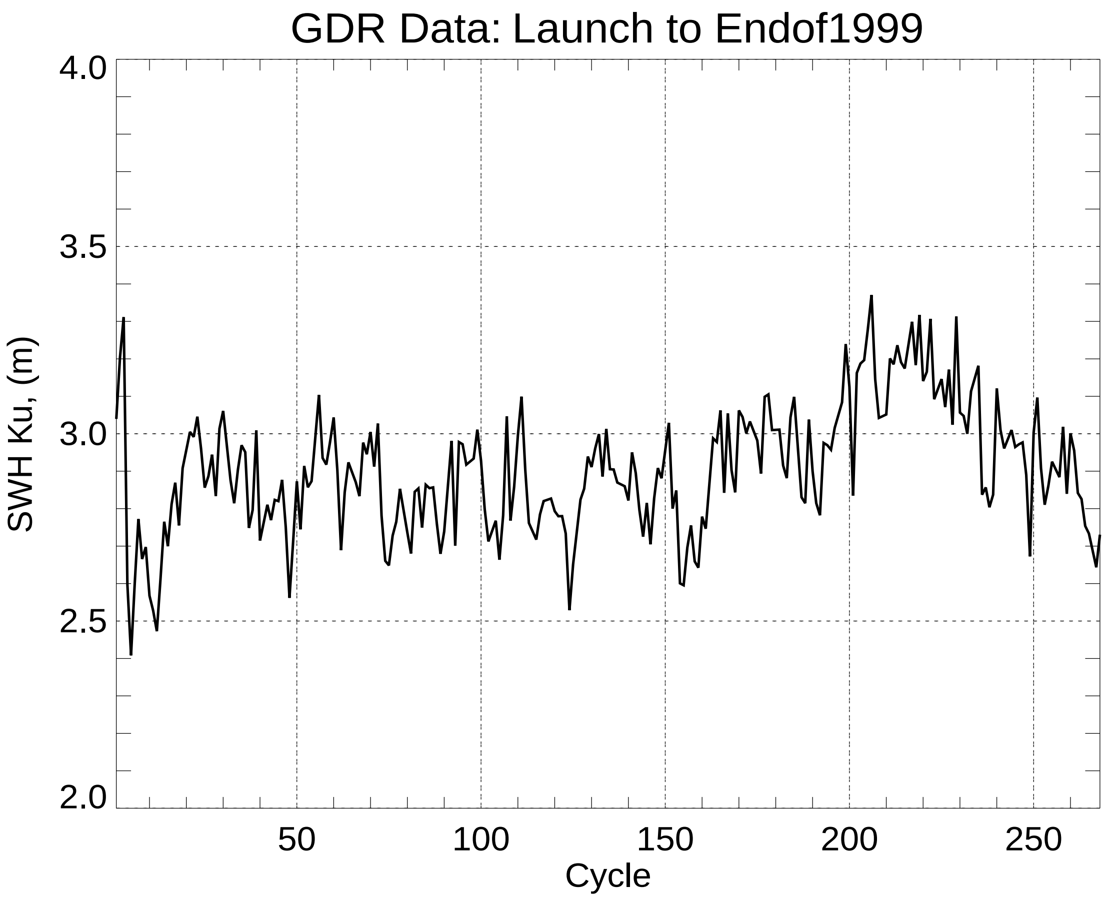

Figure 2-8 Cycle-Average Ku-Band Significant Wave Height in Meters

and continuing until Side A turnoff, the average range rms increased to 20.7 mm, generally following the trend of the false (instrument-related) swh increases.

Subsequent to the turning-on of Side B, the Ku Height RMS values have returned to normal values.

2.4.5 Waveform Monitoring

Selected telemetered waveform gates during CAL-2 and STANDBY modes are monitored daily, to discern waveform changes throughout the mission. CAL-2 waveform sets are generally available twice per day, during calibrations. STANDBY waveforms are generally available four times per day, since the altimeter passes through STANDBY mode just prior to and immediately after each CALIBRATE mode. The relationship of telemetered waveform sample numbers to the onboard waveform sample numbers is listed in Table 6.2.1 of the February 1994 Engineering Assessment Report.

For both Ku-Band and C-Band, the monitored waveform samples are as follows: CAL-2 gates 23, 29, 48, and 93; and STANDBY gates 38, 39, 68, and 69. The Ku-Band waveform sample history is shown in Figure 2-10 "Ku-Band CAL-2 Waveform Sample History" on page 2-15 and in Figure 2-11 "Ku-Band STANDBY Sample History" on page 2-16 for CAL-2 and STANDBY, respectively. The C-Band waveform history is depicted in Figure 2-12 "C-Band CAL-2 Waveform Samples" on page 2-17 and in Figure 2-13 "C-Band STANDBY Waveform Samples" on page 2-18, respectively, for CAL-2 and STANDBY.

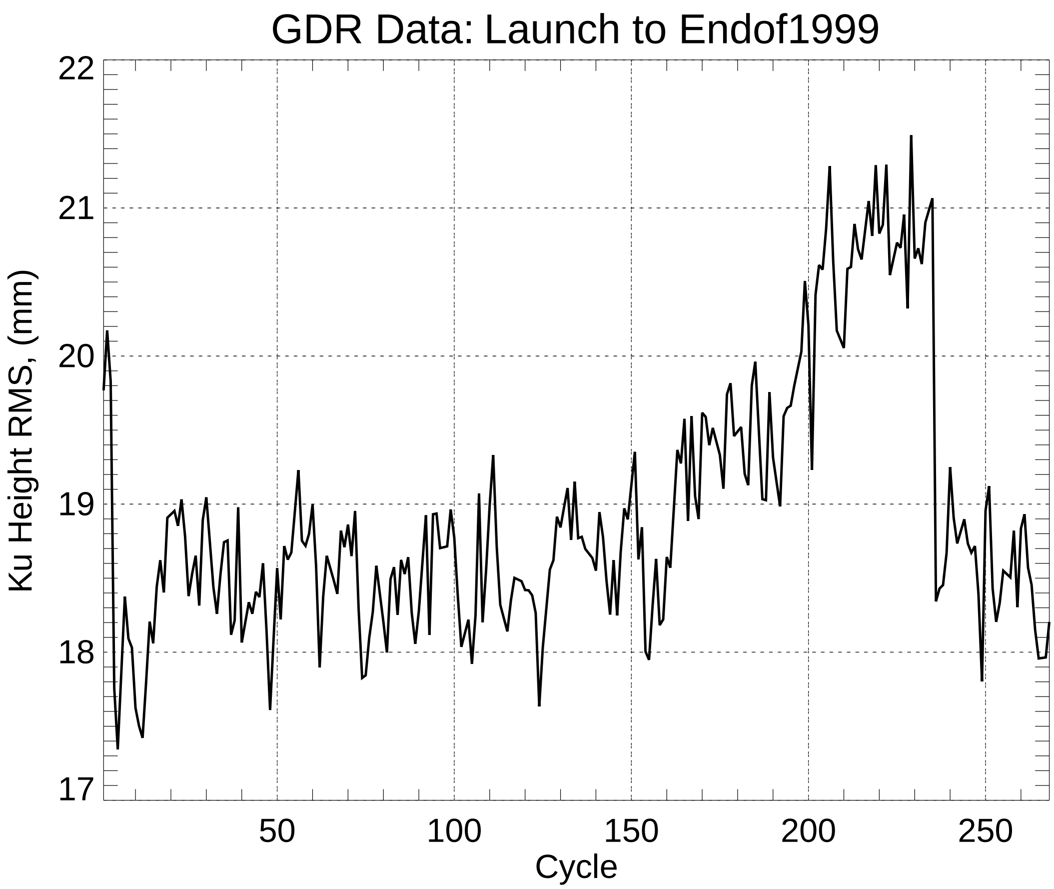

Figure 2-9 Cycle-Average Ku-Band Range RMS in Millimeters

The monitored Ku-Band CAL-2 waveform samples for Sides A and B in Figure 2-10 have each varied less than 1% throughout the mission, and exhibit little or no temperature dependence.

The Ku-Band STANDBY waveform samples in Figure 2-11, however, have a slight inverse dependence on temperature (launch-to-date temperatures are shown in Figure 2-14 on the same horizontal time scale as the waveform samples). From the time of Side B turn-on, each of the four sampled gates quickly increased between 5% and 20%, and have then remained fairly steady. Gate 39, in particular, does not show the steady power decrease that Side A exhibited. Gate 69 appears to be decreasing slightly, similar to Side A, but with a smaller magnitude.

The Side B C-Band CAL-2 waveforms samples, shown in Figure 2-12, are similar to the Ku-Band CAL-2 waveforms in that they have varied less than about 1%, and exhibit no apparent temperature dependence.

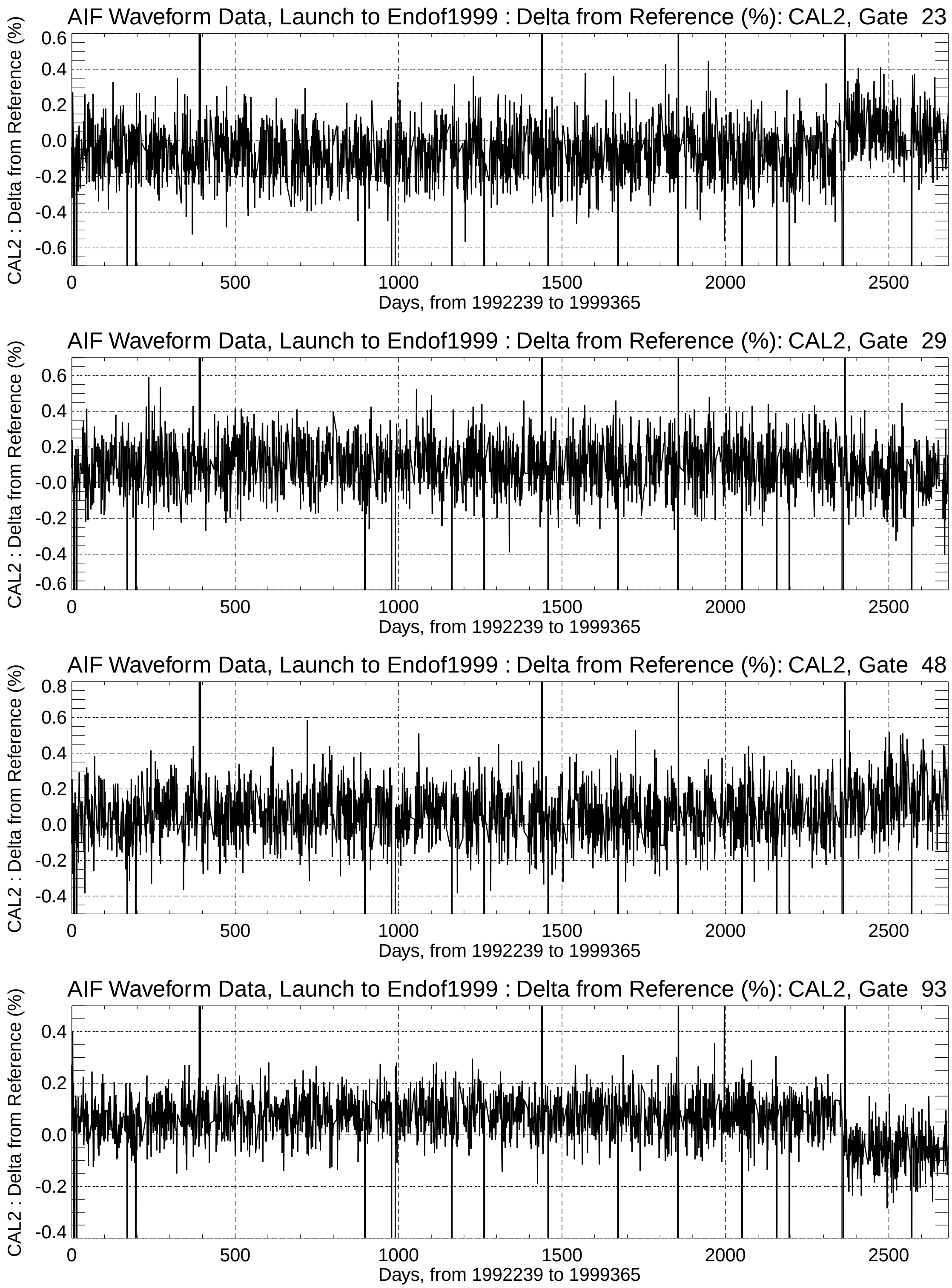

Figure 2-10 Ku-Band CAL-2 Waveform Sample History

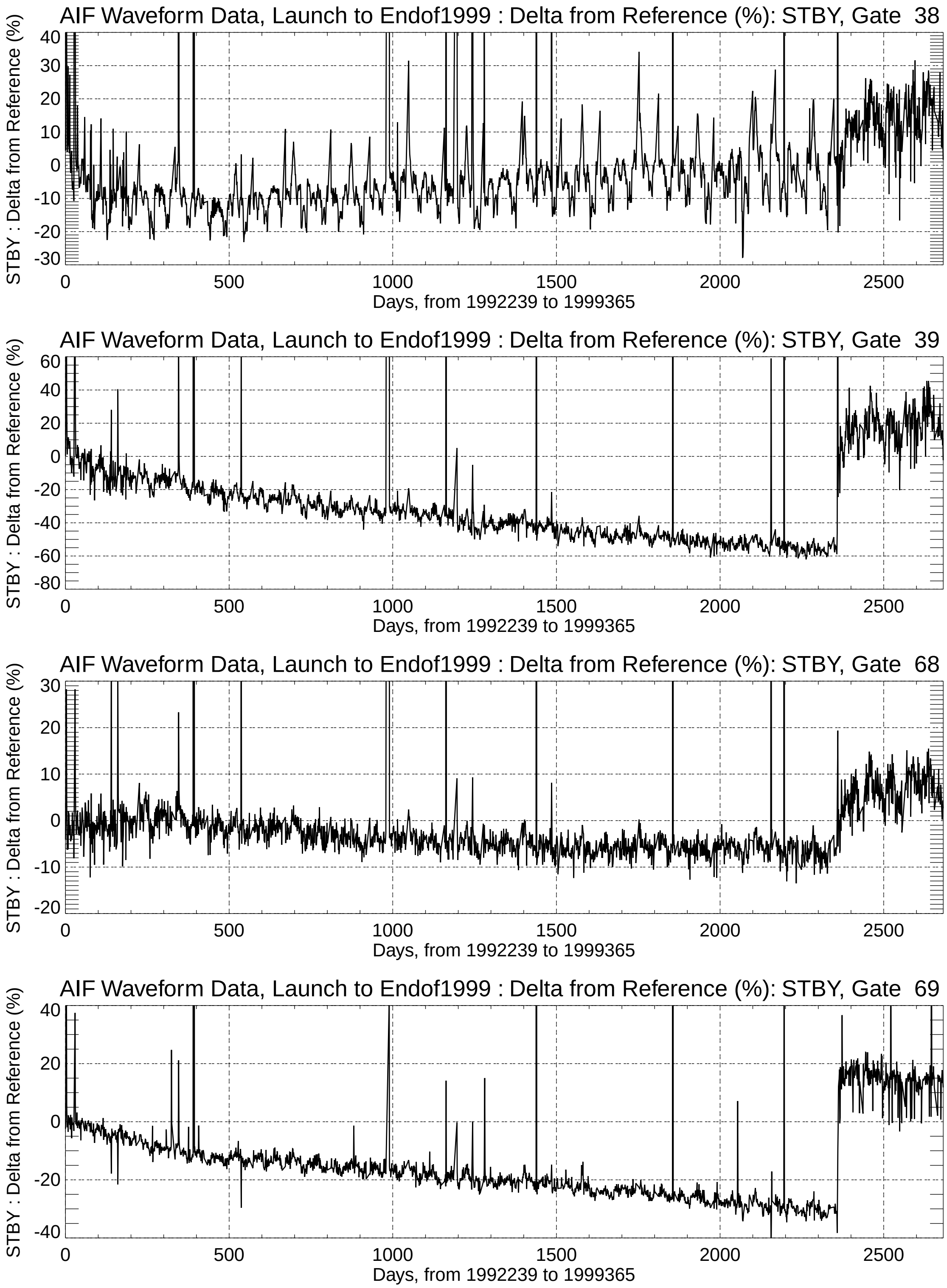

Figure 2-11 Ku-Band STANDBY Sample History

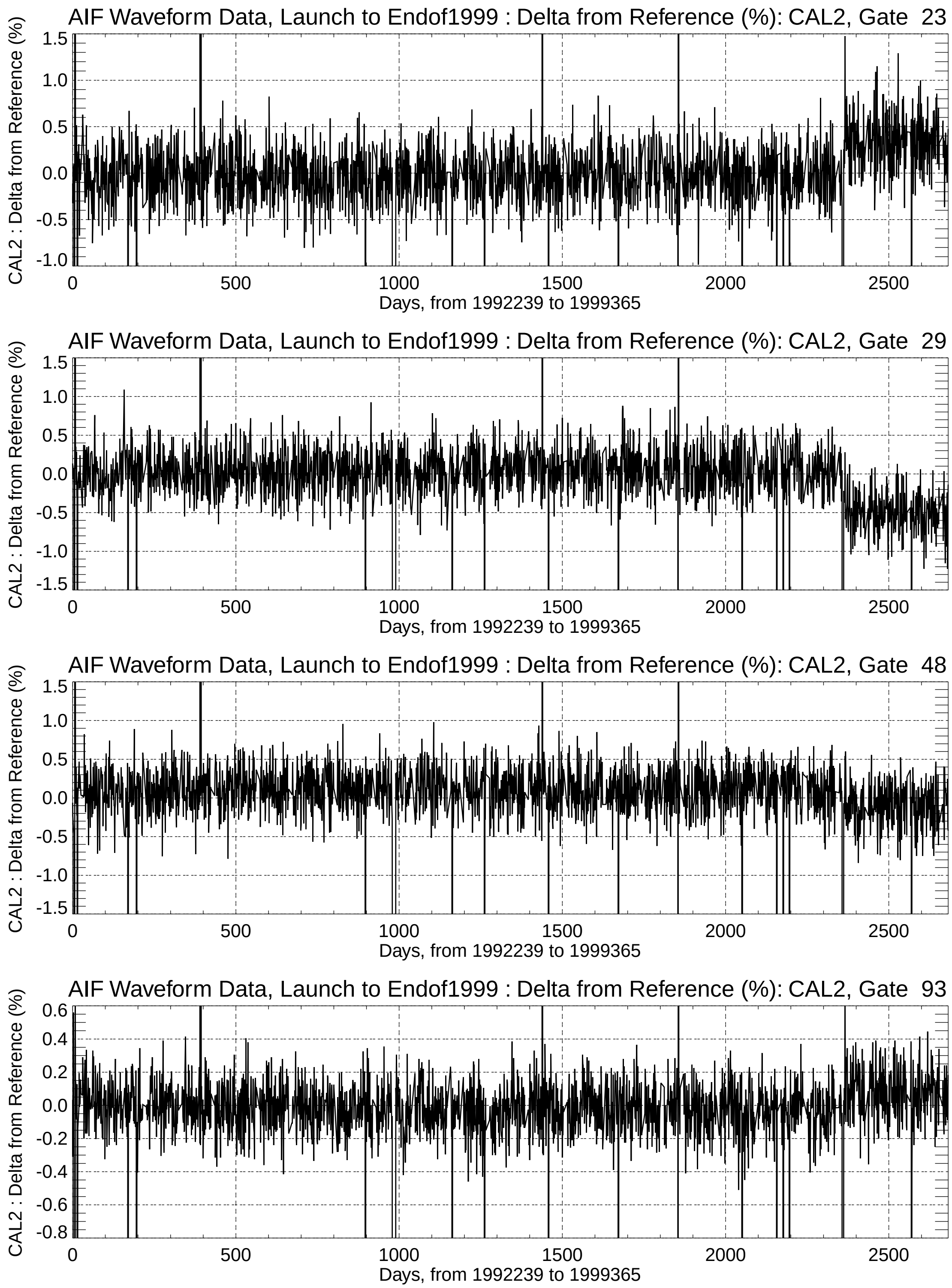

Figure 2-12 C-Band CAL-2 Waveform Samples

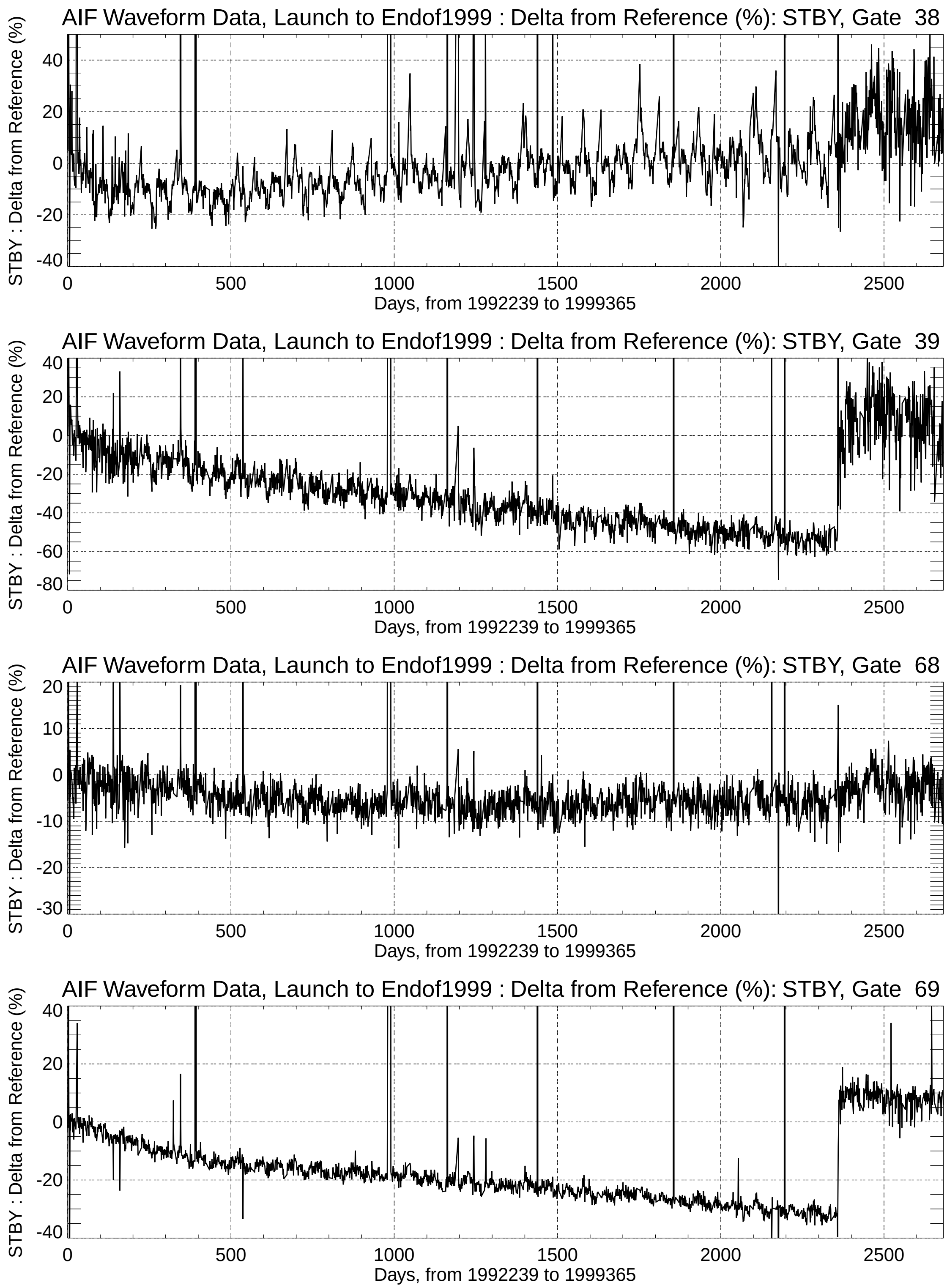

Figure 2-13 C-Band STANDBY Waveform Samples

The C-Band STANDBY waveform samples, shown in Figure 2-13, are also similar to their counterpart Ku-Band STANDBY waveforms. Gates 38, 39, 68, and 69 have an inverse dependence on temperature, and have each experienced increases shortly after turn-on. The Side B waveforms are markedly more noisy than their Side A counterparts, and Gate 69 appears to have a downward trend similar to Side A.

2.4.6 Engineering Monitors

Altimeter temperatures, voltages, powers and currents continue to be monitored. The system remains very stable, with no significant changes since Side B turn-on. The engineering monitor plots presented in this section contain data based on 24-hour time periods, showing the average, the minimum, and the maximum values during each 24-hour period.

2.4.6.1 Temperatures

The temperatures of all 26 internal thermistors continued to be within the design temperature range and, except for the DCG Gate Array, are within the ranges experienced during the pre-launch Hot and Cold Balance Tests. The minimum / maximum values for each of the thermistors during TRACK mode remained within the bounds listed in Table 7.1 of the February 1994 Engineering Assessment Report, and they compose plots 2 through 27 in Figure 2-14 "Engineering Monitor Histories" on page 2-20.

The DCG Gate Array temperature is about 30 degrees higher than experienced during pre-launch testing. However, the temperature has remained stable since Side B turn-on, and a lifetime thermal analysis of a similar DCG Gate Array unit indicates no concern.

Although not used during our routine monitoring, several of the altimeter-related baseplate temperature monitors serviced by Remote Interface Unit (RIU) 6B became uncalibrated on day 17 of 1995. The affected temperature monitors are listed in Section 2.2.6.1 of the 1996 Engineering Assessment Report. An abrupt change in the values occurred on that date, apparently due to a change in the current which is applied to the thermistor circuits

2.4.6.2 Voltages, Powers and Currents

The altimeter's 17 monitors for voltages, powers and currents remained at consistent levels, with little deviations. Their launch-to-date histories are also shown in Figure 2-14 "Engineering Monitor Histories".

The eight voltages [LVPS +12V, LVPS +28V, LVPS +15V, LVPS -15V, LVPS +5V(5%), LVPS +5V(1%), LVPS -5.2V and LVPS -6V], have changed very little since Side B turn-on.

The following changes since turn-on of Side B are noted:

- The amperage of the TWA Helix has linearly decreased about 0.00005 amps.
- The C-Band Transmit Power has decreased approximately 0.6 watts since turn-on, but appears to have leveled-off.

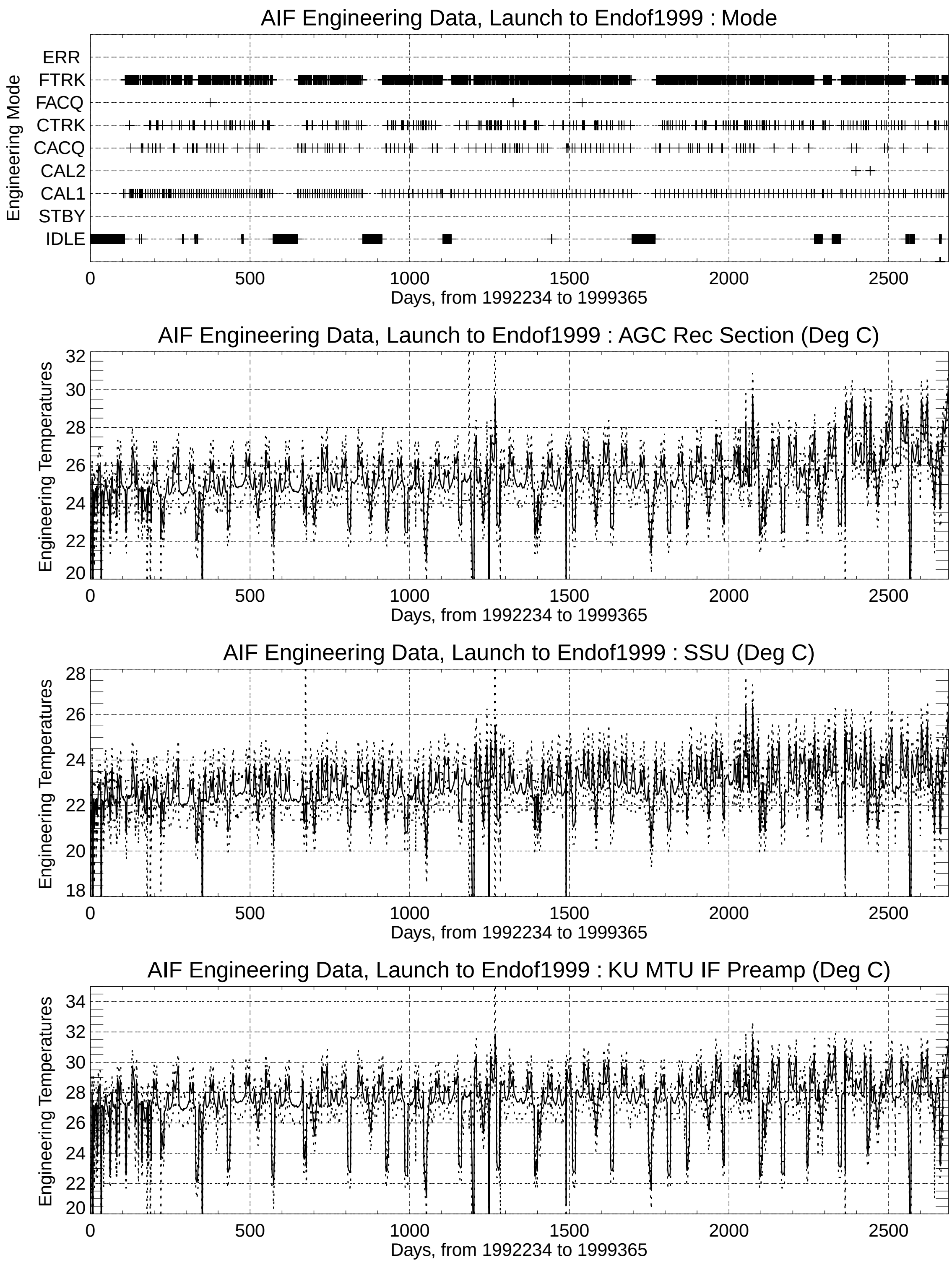

Figure 2-14 Engineering Monitor Histories

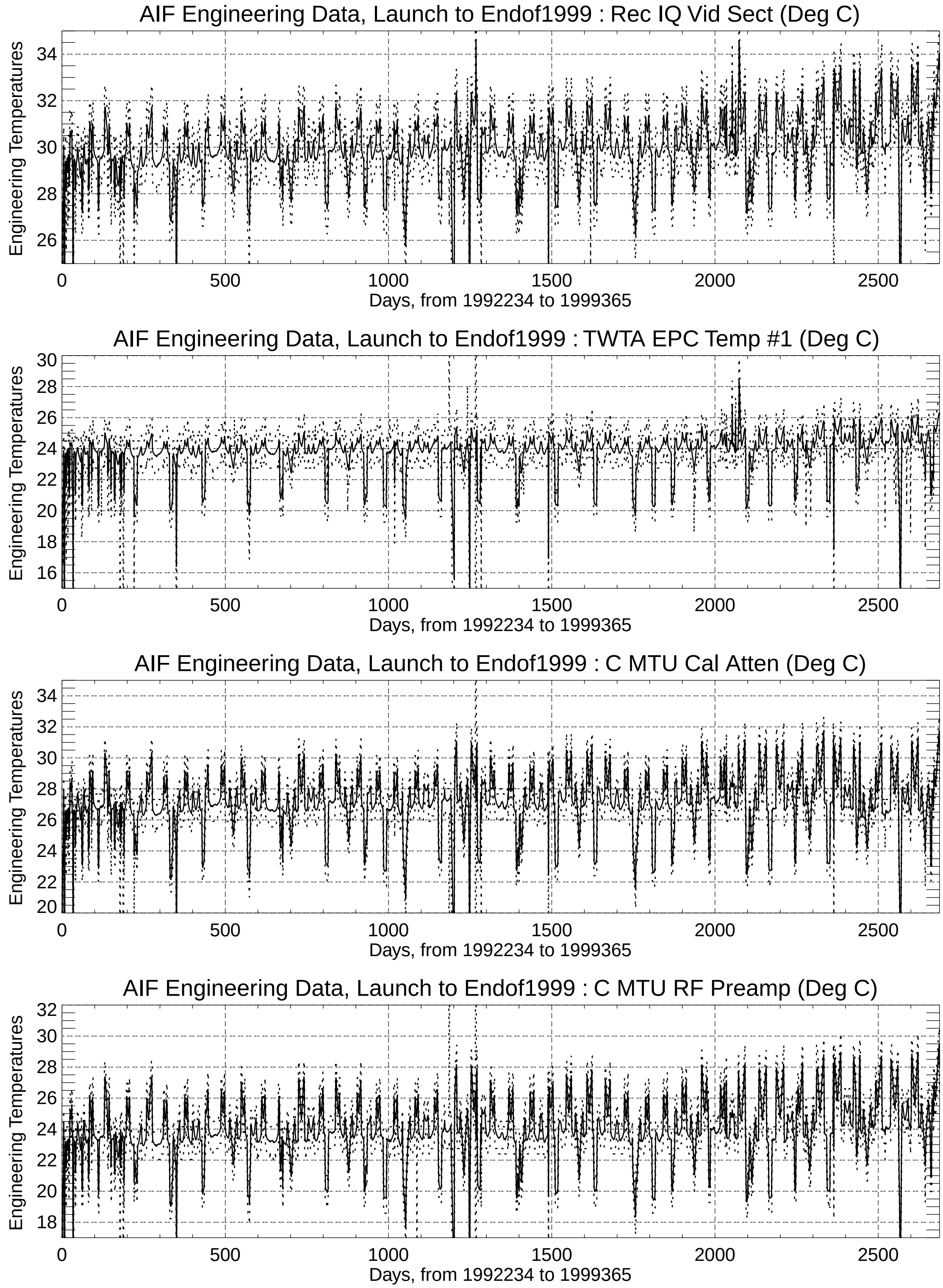

Figure 2-14 Engineering Monitor Histories (Continued)

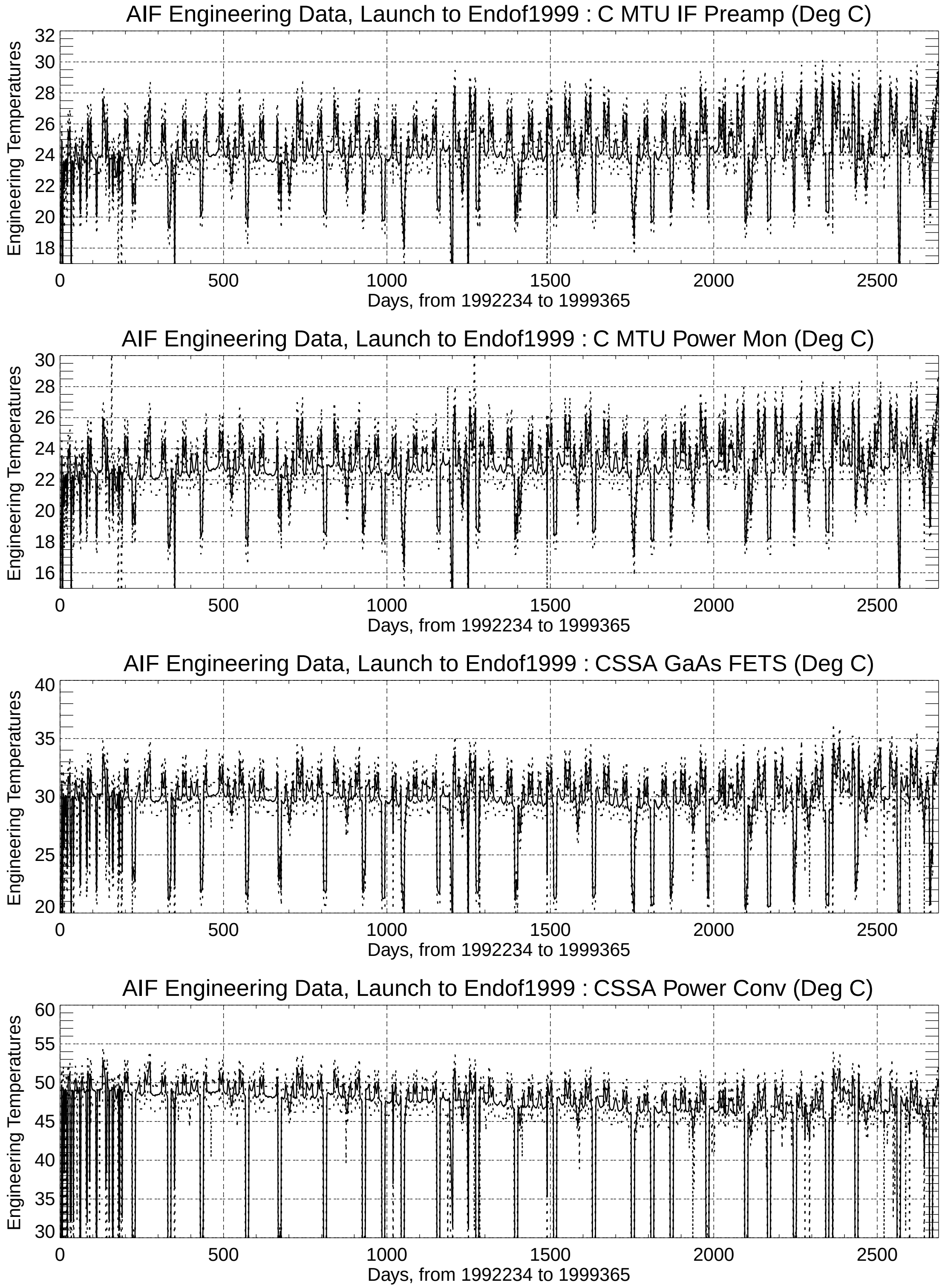

Figure 2-14 Engineering Monitor Histories (Continued)

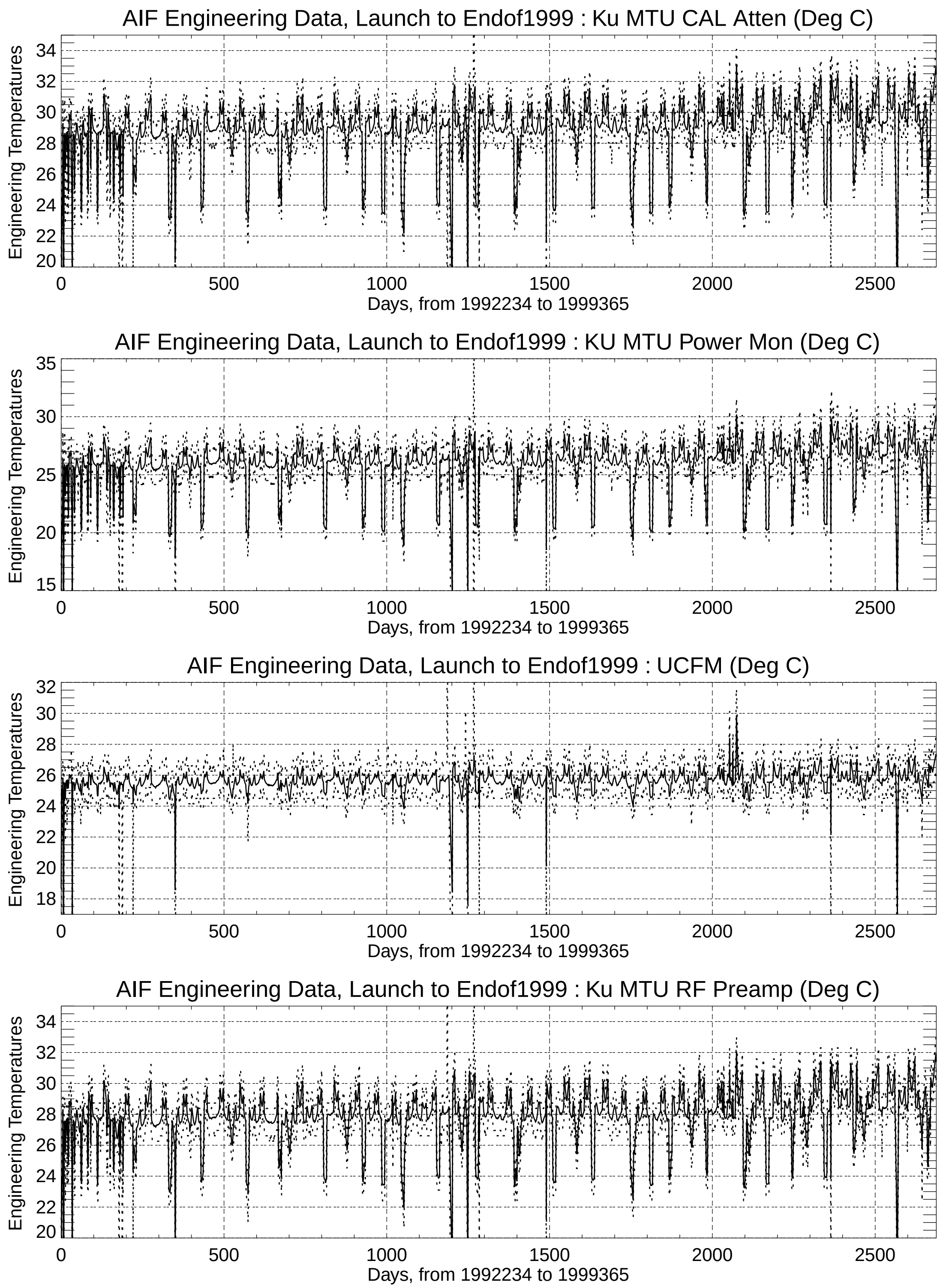

Figure 2-14 Engineering Monitor Histories (Continued)

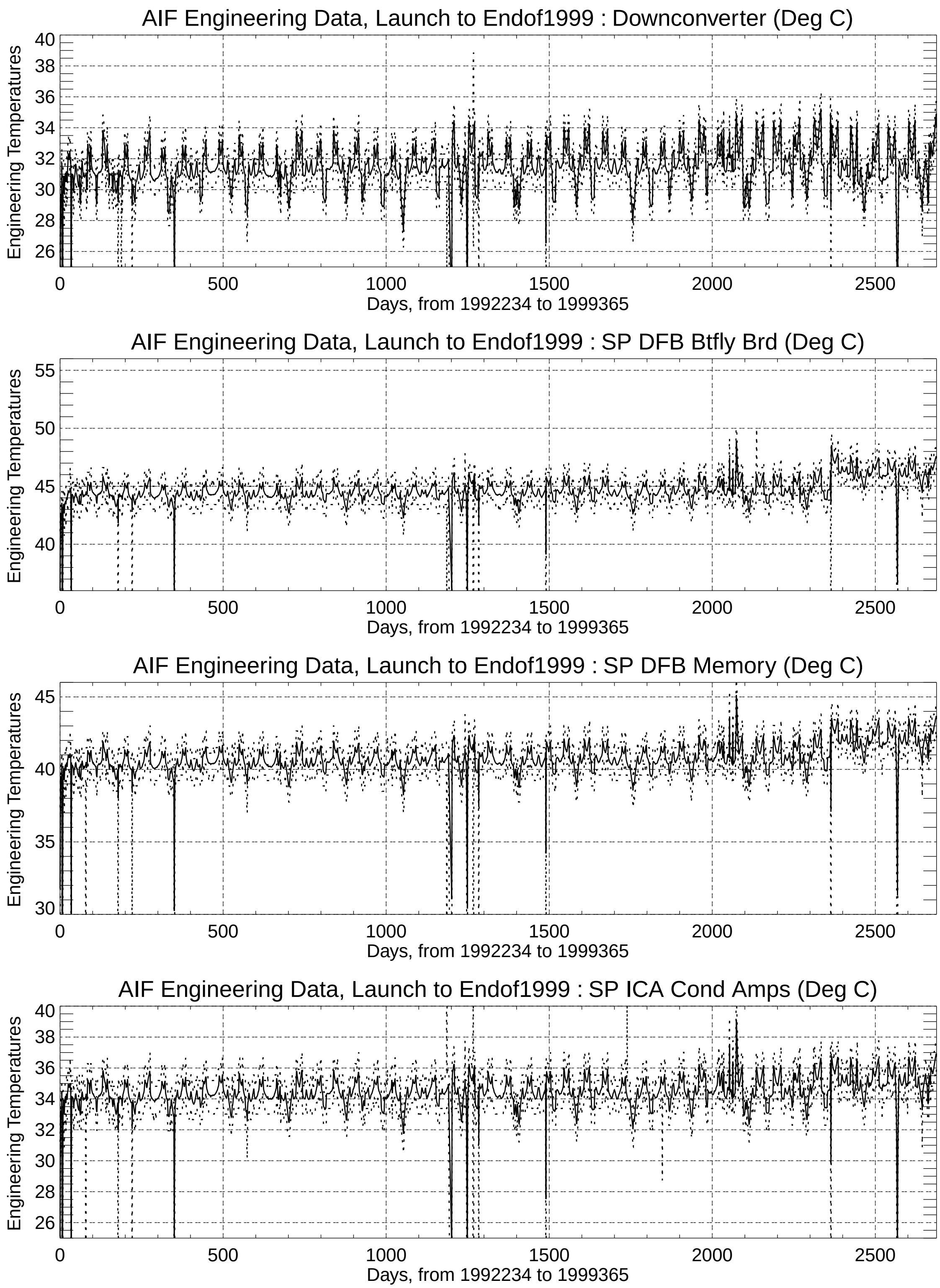

Figure 2-14 Engineering Monitor Histories (Continued)

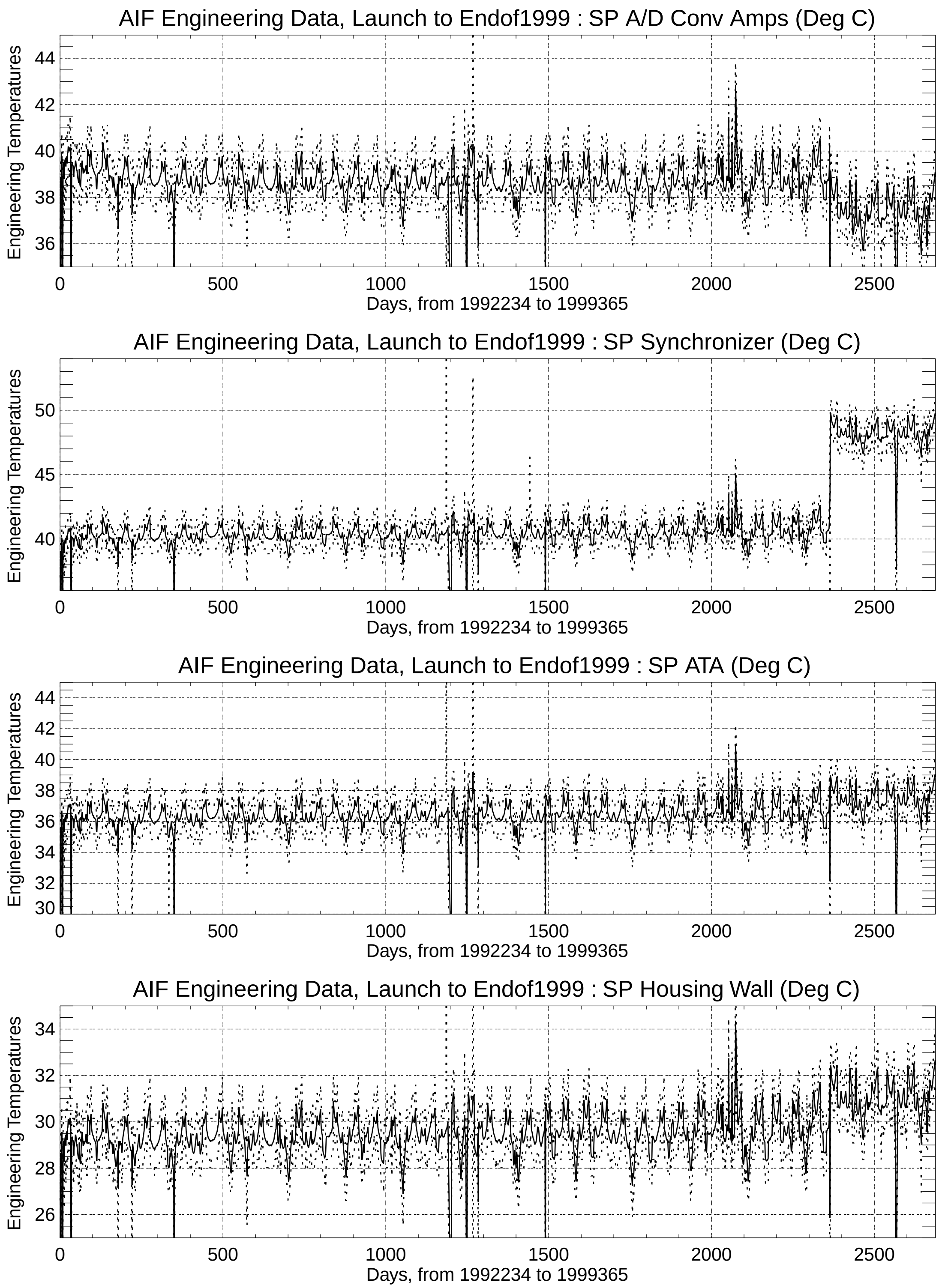

Figure 2-14 Engineering Monitor Histories (Continued)

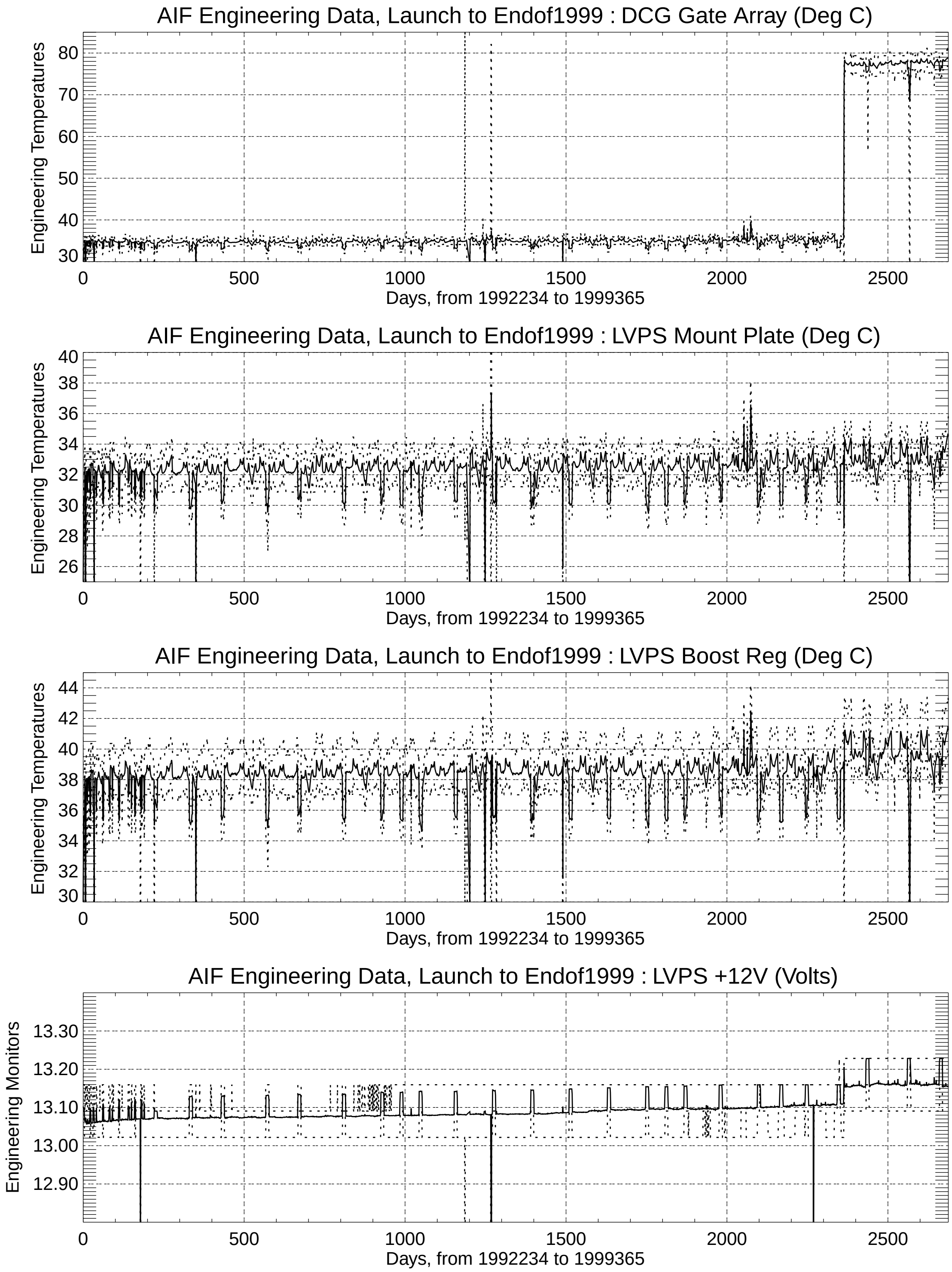

Figure 2-14 Engineering Monitor Histories (Continued)

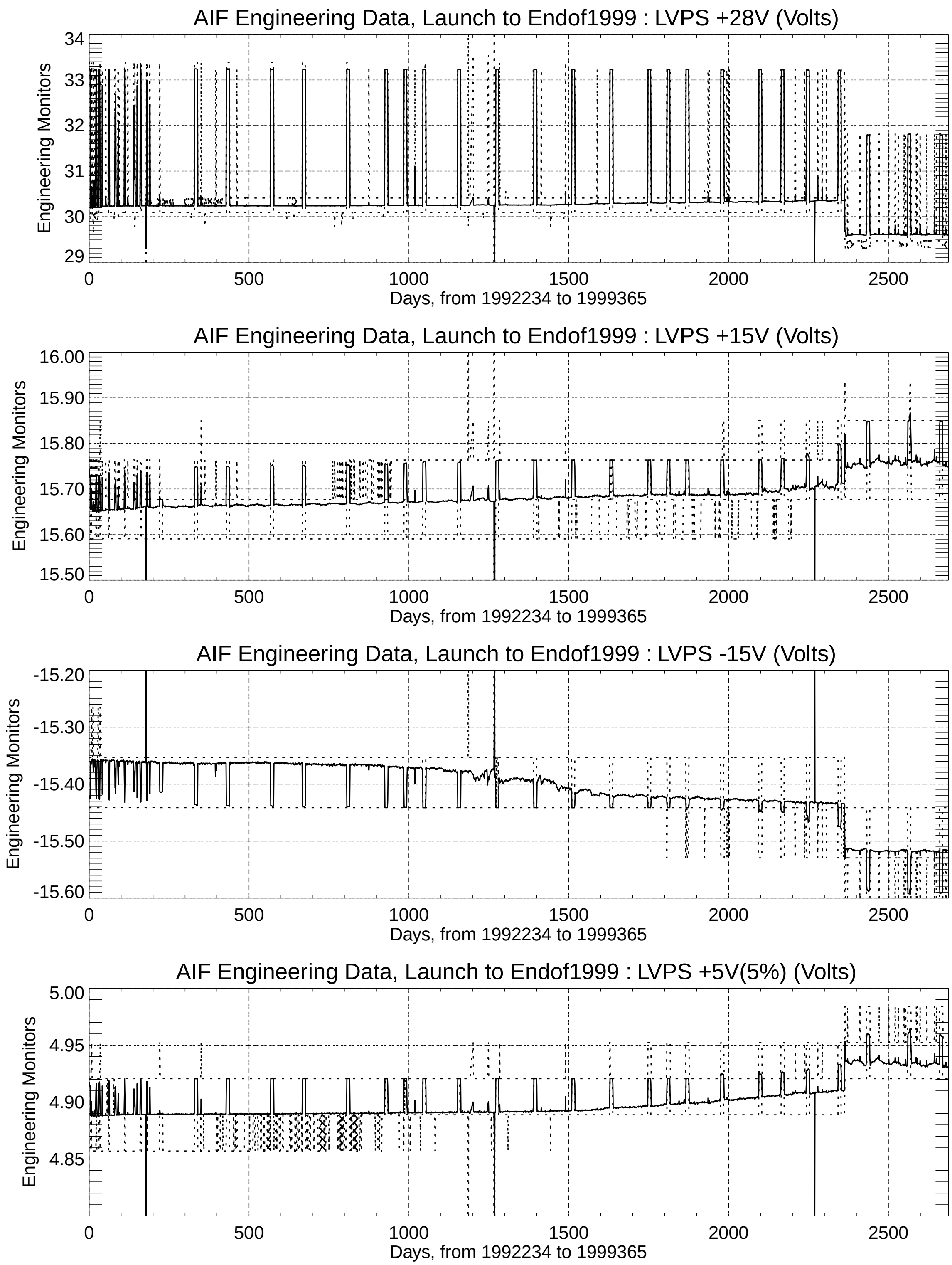

Figure 2-14 Engineering Monitor Histories (Continued)

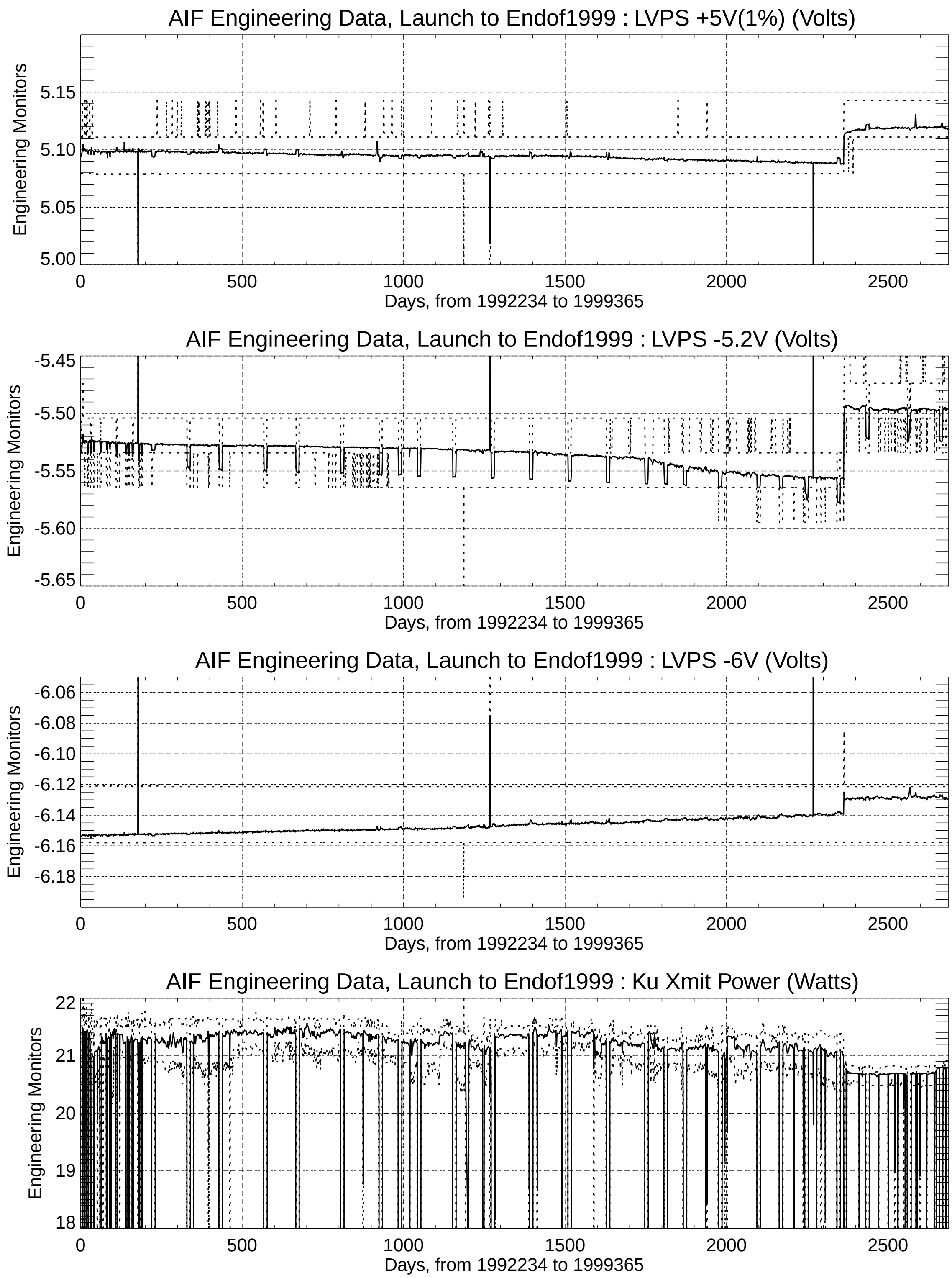

Figure 2-14 Engineering Monitor Histories (Continued)

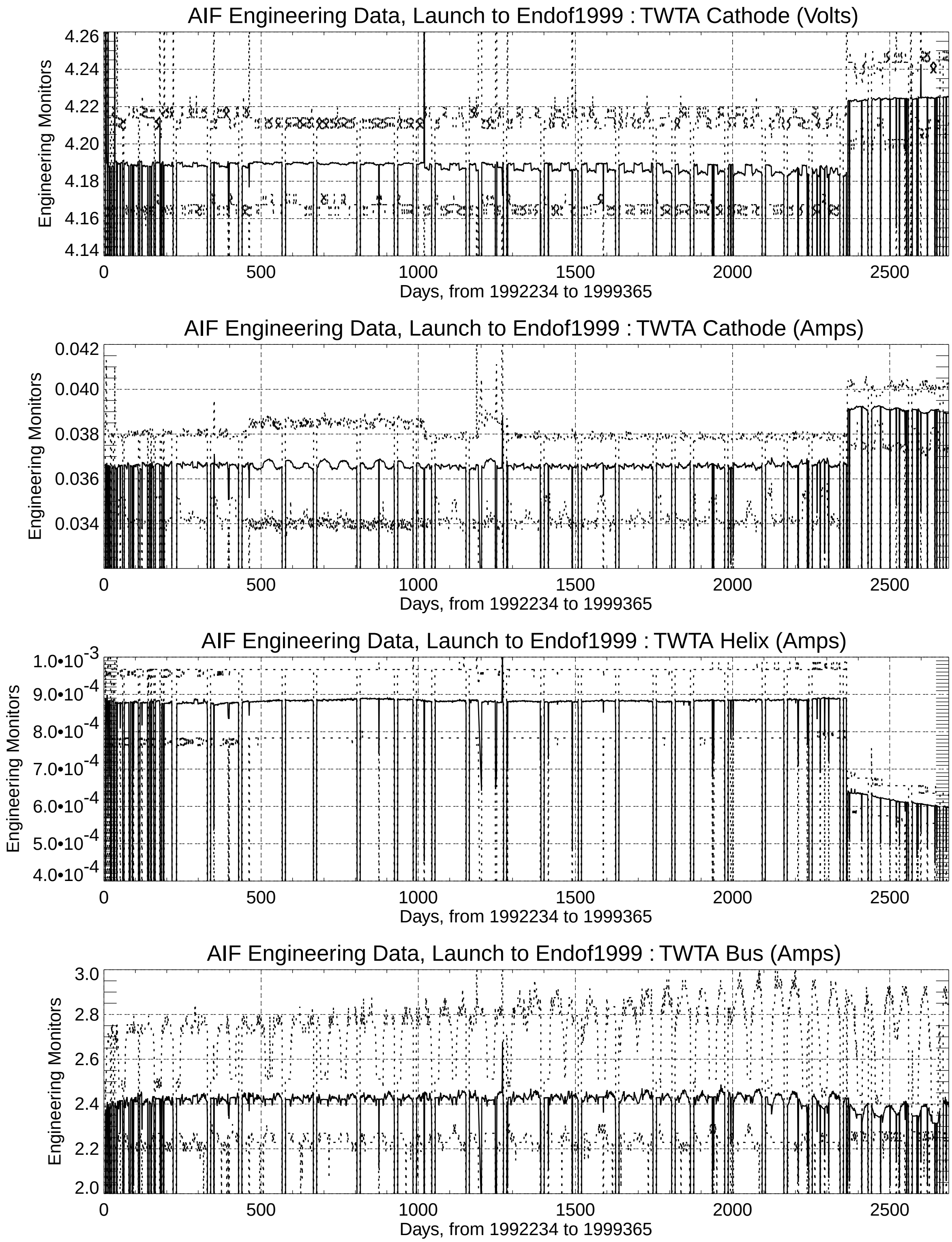

Figure 2-14 Engineering Monitor Histories (Continued)

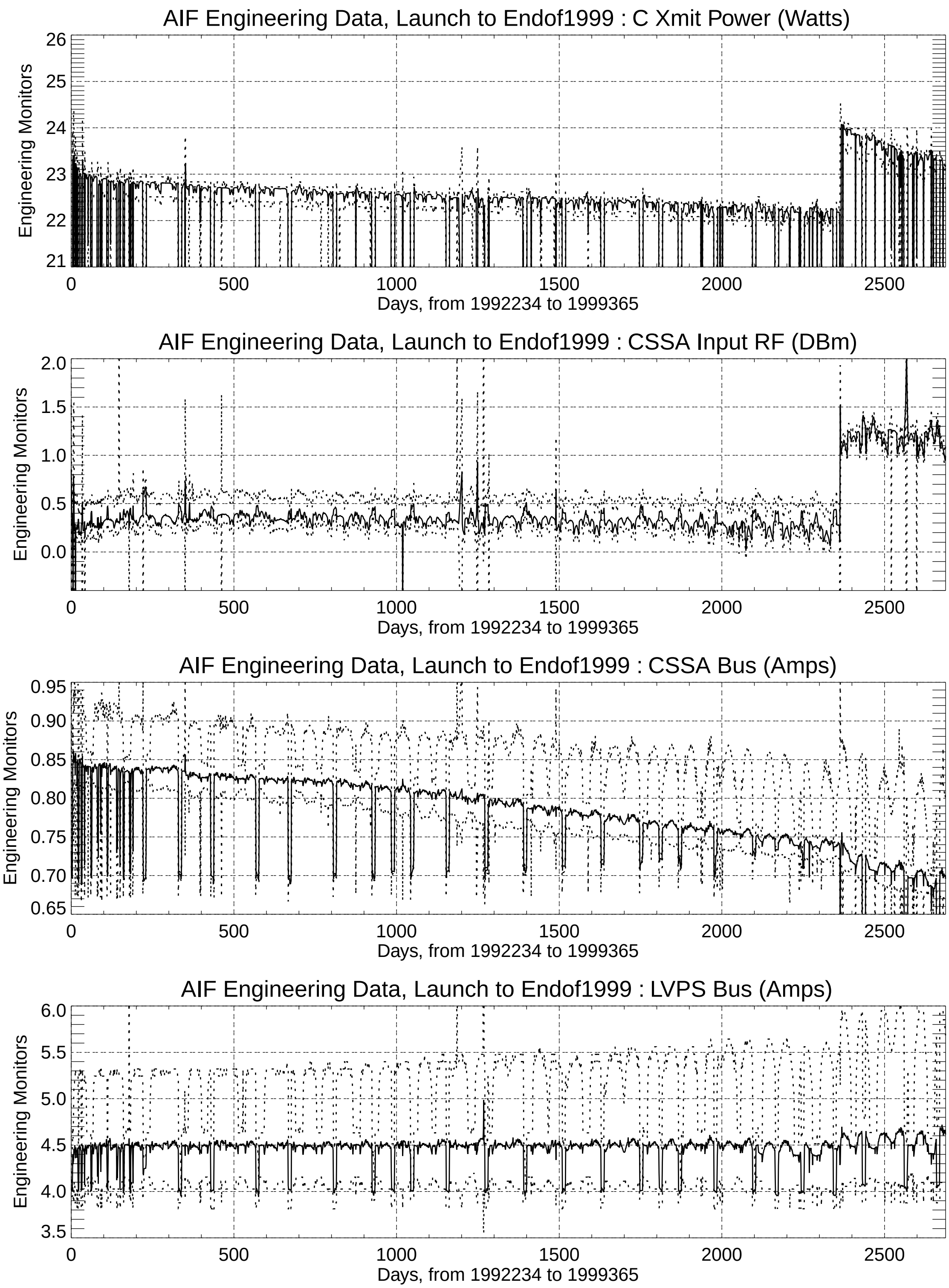

Figure 2-14 Engineering Monitor Histories (Continued)

- There has been a gradual decrease in the CSSA Bus current level; the level has decreased 0.05 amp since turn-on.

2.4.7 Single Event Upsets

There have been a total of 378 Single Event Upsets (SEUs) from launch to the beginning of 2000. The vast majority of them occurred in the South Atlantic Anomaly, as shown in Figure 2-15 "Locations of SEU Occurrences" on page 2-31.

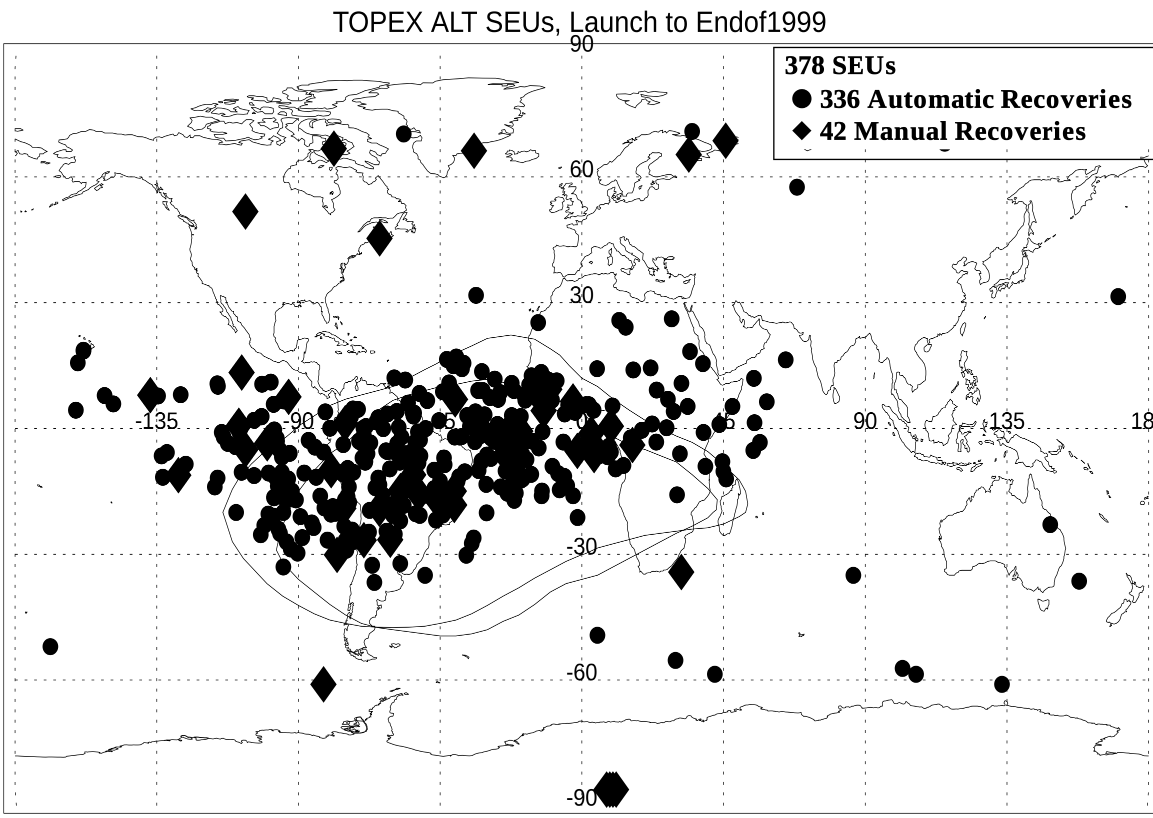

Figure 2-15 Locations of SEU Occurrences

The altimeter processor automatically recovered from 336 of the SEUs; the other 42 required manual (ground-based command) resets. While the automatic resets generally resulted in the loss of only a few seconds of data, thirteen of them had data effects of longer duration. As of the January 1, 2000, there have been a total of 52 anomalous resets (39 manual resets plus the 13 abnormal automatic resets); Table 2-2 "Anomalous Single Event Upsets" lists the dates of these 52 SEUs, along with the type of on-board reset and the duration of the effect on the data.

The dots in Figure 2-15 denote the locations of normal SEU occurrences, while the diamonds indicate that the SEU was abnormal.

The four diamonds at latitude -90 degrees were placed there because their occurrence times (and corresponding geographic locations) could not be pin-pointed due to the

Table 2-2 Anomalous Single Event Upsets

Year	Day	Duration (Hr)	Reset Type
Side A			
1992	247	11.0	Automatic
1992	354	16.8	Manual
1993	012	0.5	Automatic
1993	230	1.3	Automatic
1993	264	14.5	Manual
1993	266	7.5	Manual
1993	307	2.3	Manual
1993	330	8.3	Manual
1994	001	3.8	Manual
1994	112	1.1	Manual
1994	256	4.3	Manual
1994	271	0.1	Automatic
1994	288	2.5	Manual
1994	294	1.3	Automatic
1994	324	3.1	Manual
1995	012	0.7	Automatic
1995	083	1.6	Manual
1995	132	0.2	Manual
1995	157	8.4	Manual
1995	251	3.9	Manual
1995	306	3.4	Manual
1995	325	1.8	Manual
1995	327	3.5	Manual
1995	361	3.3	Manual
1996	018	2.0	Automatic
1996	041	3.1	Manual
1996	057	2.2	Manual
1996	077	1.6	Manual
1996	162	0.8	Automatic

Table 2-2 Anomalous Single Event Upsets (Continued)

Year	Day	Duration (Hr)	Reset Type
Side A			
1996	185	0.7	Automatic
1996	197	1.1	Manual
1996	217	2.8	Manual
1996	226	4.9	Manual
1996	362	4.8	Manual
1997	048	0.1	Automatic
1997	099	1.0	Manual
1997	191	0.1	Automatic
1997	237	1.6	Manual
1997	253	4.1	Manual
1997	268	2.8	Manual
1997	332	3.5	Manual
1998	013	3.9	Manual
1998	164	3.4	Manual
1998	243	2.7	Manual
1998	254	2.5	Manual
1998	296	2.0	Automatic
Side B			
1999	071	0.7	Manual
1999	198	5.6	Manual
1999	223	1.6	Manual
1999	246	13.0	Manual
1999	276	3.1	Manual
1999	280	0.1	Automatic
		Total = 181.4 Hours	

altimeter's being in IDLE mode, and because procedures had not, at that time, been implemented to record the IDLE-mode SEU times.

There were a total of 56 SEUs since the Side B turn-on on February 10, 1999, or about one every 5.8 days. For the total mission, the SEU occurrence average has been one every 6.8 days.

There were five anomalous Side B SEUs since the beginning of 1999; for four of them, the TOPEX/POSEIDON POCC reset the altimeter by transmitting Command Block SA28 (Processor Error Reset in Track Mode).

2.5 Launch-to-Date Key Events

The key events for TOPEX Altimeter Side B since its on-orbit turn-on are summarized in the NASA Altimeter - Key Events table given below.

In response to the altimeter's PTR change (see Section 3.3) during Side A, a Cal Sweep software patch was developed, and was uploaded on day 250 of 1998. The purpose of this patch is to monitor the shape of the altimeter's CAL-1 waveform, looking for changes over time. Cal Sweeps are now regularly performed every 30 days, beginning with Side A on day 251 of 1998 and continuing through Side B operations.

Table 2-3 NASA Altimeter - Key Events

Day	Side B Event
1999/041	Commanded Side B to IDLE Mode and Uploaded Memory Patches
1999/042	Commanded Side B to STANDBY and then to TRACK Mode
1999/042	Side B Testing, including: Mode Checks, Cal-Sweep, and Waveform Leakage Tests
1999/043	Additional Testing, including: Cal-Sweep, Waveform Leakage Tests, and Gate-Shift Tests
1999/048	Gate Shift Tests (lost 3.1 hours of data)
1999/049	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/049-050	Off-Nadir Tests
1999/050	Began First Side B Operational Cycle [Cycle 237]
1999/223	C-Band CAMPIN was Autonomously Disabled
1999/236	Commanding for New Parameter File, to Increase AGC Minimum from 13 to 15 dB (lost 0.1 hours of overland data).
1999/237	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/238	Changed to IDLE Mode for SSALT
1999/243	Spacecraft Safehold, after a reset of central data processing unit. ALT was automatically turned OFF.
1999/243	Commanded ALT back to IDLE Mode. Total OFF time was 15.7 hours.
1999/244	Uploaded full memory dump command. ALT remains in IDLE.
1999/245	ALT turned OFF during Attitude Control Electronics switchover
1999/246	Commanded ALT back to IDLE Mode and Uploaded full memory dump command. ALT remains in IDLE. OFF time was 7.9 hours.
1999/248	Returned to TRACK Mode
1999/252	Digital Filter Bank Calibration (lost 0.3 hours of overland data)
1999/265	Sent Commands in Attempt to Improve Acquisition. Lost 1.1 hours of land and ocean data. Commanding was Unsuccessful.
1999/268	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/276	Ku-Band Autonomously Switched to Side A Transmit (lost 3.1 hours of data)
1999/298	Cal-Sweep Test (lost 0.4 hours of overland data)

Table 2-3 NASA Altimeter - Key Events (Continued)

Day	Side B Event
1999/327	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/337	Changed to IDLE Mode for SSALT
1999/347	Returned to TRACK Mode
1999/357	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/360	SEU resulted in corruption of the engineering Pass Count value. No apparent effect on ALT science data.

2.6 Land-to-Water Acquisition Times

In the summer of 1999, it was brought to our attention by colleague Joel Dorandeu of Collecte Localisation Satellites (CLS) that a few of the Side B land-to-water acquisition times were anomalously slow. An example of this is depicted in Figure 2-16 where, for Cycle 255, delayed acquisitions are depicted by the darkened groundtrack lines. Most prominent in the figure are slow acquisition periods off the southeastern coasts of Greenland, Iceland, and Australia. Our subsequent analysis indicated that these occasional slow land-to-water acquisitions had occurred since the time of Side B turn-on.

Although these abnormal acquisitions resulted in a loss of only about 0.02% of ocean-tracking data, we wished to understand and rectify the anomalies. The parameter file C3502840 (which had been in use since February 1995) was modified to increase the AGC Minimum (bytes 67-70) from a value of 13 dB to a value of 15 dB, and the new parameter file was named AGCMIN15. Uploading of this file had no observed positive, or negative, effect on the occasional acquisition delays.

Onboard software changes were being considered when a Spacecraft-level Safehold occurred on day 243 of 1999, and the altimeter was turned off for a total of 24 hours. Subsequent to the Safehold, the acquisition anomaly no longer was in evidence, as depicted for cycle 267 in Figure 2-17.

We continue to monitor the land-to-water acquisitions, and the anomaly has not recurred. The software patch in on-hold, and we continue to use the AGCMIN15 parameter file as our standard.

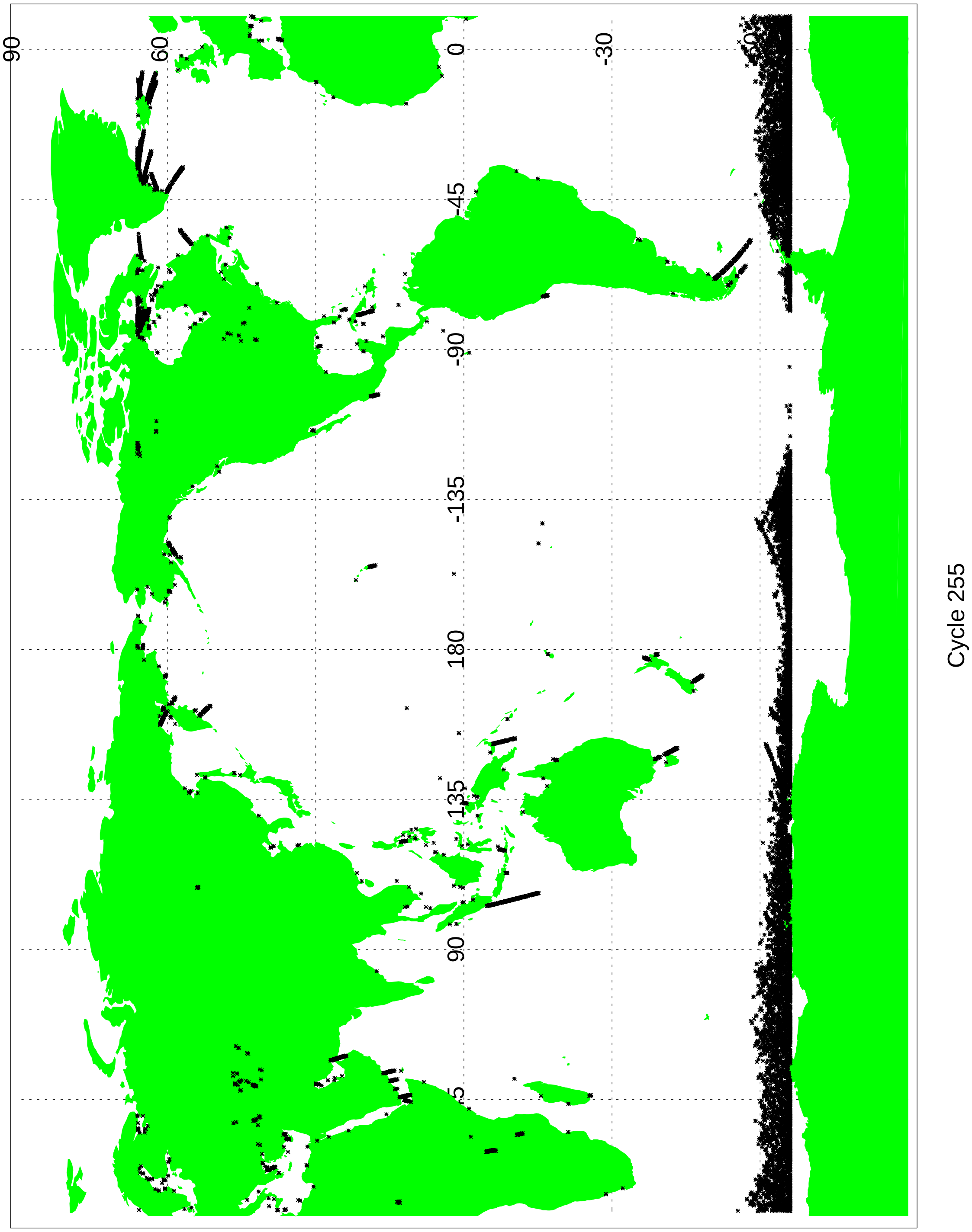

Figure 2-16 Cycle 255, with Areas of Land-to-Water Acquisition Anomalies

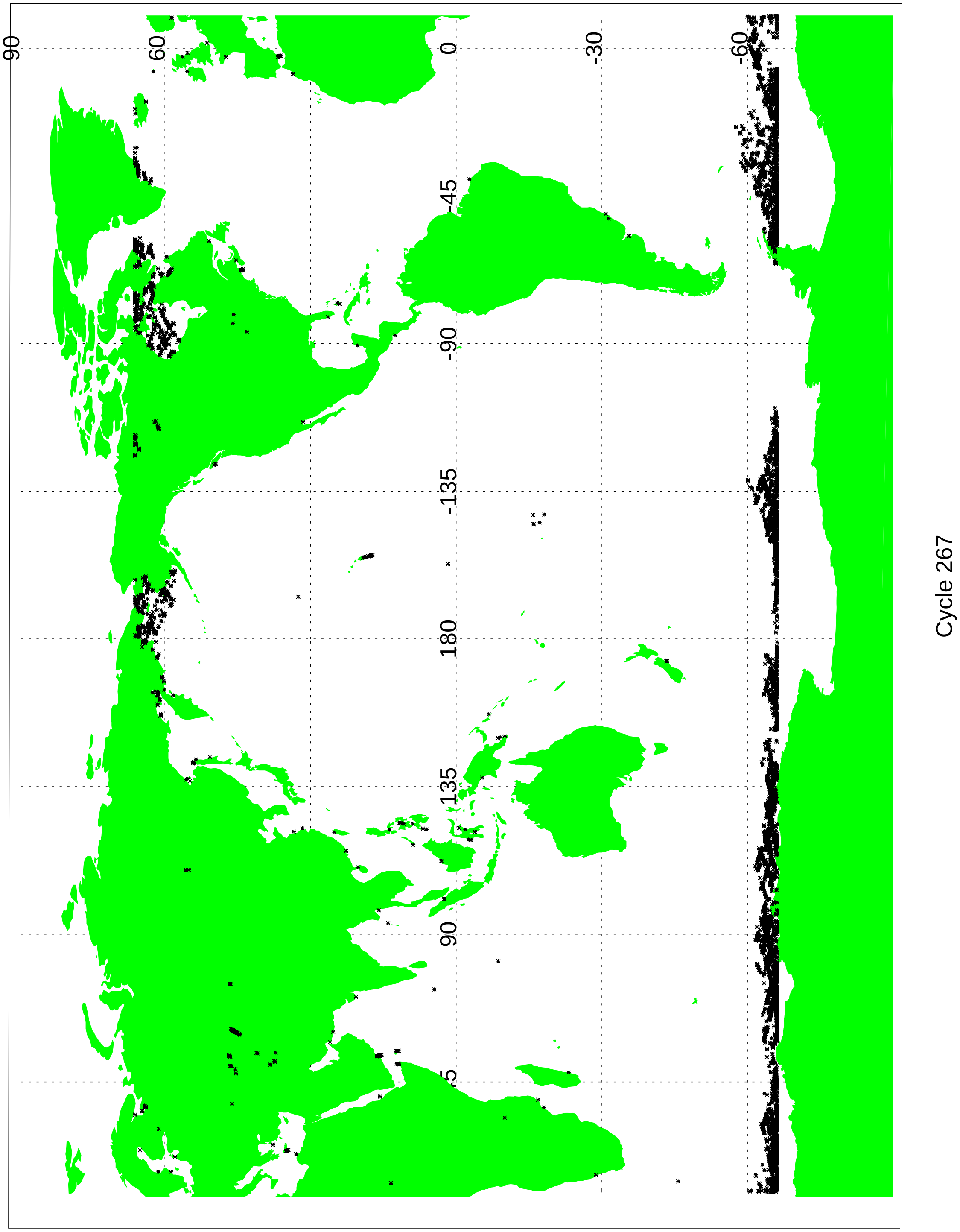

Figure 2-17 Cycle 267, with No Evidence of Land-to-Water Acquisition Anomalies

Section 3

Assessment of Instrument Performance

3.1 Range

The following range discussion is restricted to TOPEX Side B operation in 1999. Previous years' assessment updates have supplied cumulative results for Side A from launch to the end of the assessment update period, so last year's assessment update provides the entire set of TOPEX Side A results. Side B is effectively a new altimeter, and this year's assessment update will start with the Side B Turn-on.

This report section discusses the Side B Cal-1 Step-5 Ku- and C-band delta ranges. The Calibration Mode was briefly reviewed in Section 2.3. The Ku- and C-band delta ranges have been processed to form a set of delta combined range values, where "combined" refers to the weighted sum of Ku- and C-band delta ranges which compensates for the ionospheric electron path delay. There are about twenty combined delta ranges for each TOPEX cycle, corresponding to two calibrations per day during the 10-day cycle. Early in Side A operation we developed a CAL-1 processing scheme to remove the effects of a 7.3 mm range quantization in the TOPEX internal calibration mode. The Side B is almost identical to Side A, the same calibration mode quantization is present in the CAL-1 delta range data, and we have used the same processing method to remove these quantization effects.

In previous years we had found that the Side A delta ranges had a temperature dependence. There are about two dozen different temperatures monitored within the TOPEX altimeter, and it is not possible to determine which of these is the most important to range bias. For our Side A analysis we had used the temperature of the upconverter / frequency multiplier unit (the UCFM), designating this temperature as T_u. The Ku-band delta range and the combined delta range varied somewhat with T_u, and we had found a simple quadratic correction of the combined delta range for T_u variation. Our previous years' assessment updates had tables of the range bias results with and without the correction for T_u, and we recommended that the TOPEX GDR data end user (who does not have easy access to the temperature data) should use the Side A combined delta range results that were NOT corrected for temperature T_u.

For Side B the behavior of delta range with temperature is somewhat different. We found that the Ku-band combined range shows practically no temperature effect but that the C-band combined result does exhibit a temperature dependence. We found that the C-band variation was more highly correlated with the receiver AGC temperature (designated T_{agc} here) than with T_u. Figure 3-1 shows the full set of Side B T_{agc} values during the calibrations for the year 1999. Figure 3-2 shows the Ku-band CAL-1 Step 5 delta range values for 1999, before and after fitting a thermal correction which is quadratic in T_{agc}, and it can be seen that the T_{agc} correction term has very little effect on the results. Figure 3-3 shows the corresponding C-band delta range values for 1999, before and after T_{agc} correction, and it can be seen that the T_{agc}

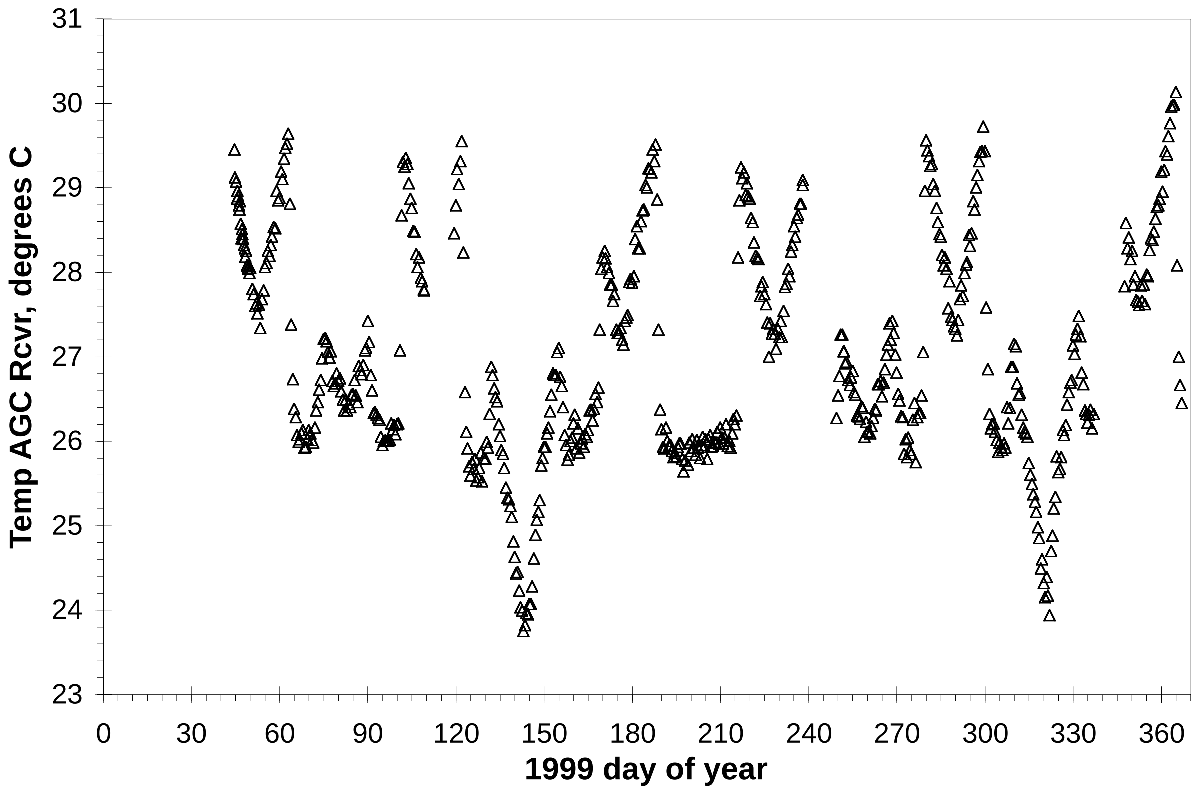

Figure 3-1 AGC Receiver Temperature vs. Time for Side B (all Cal1 Step 5 Data, Cycles 236-268)

correction term does eliminate some of the variations of the individual data relative to the general trend. Finally, Figure 3-4 shows the combined delta range results with and without T_{agc} corrections and, similar to the Ku-band, the T_{agc} corrections have little discernible effect.

As for Side A, the general trend of delta ranges is slow enough that corrections can and should be made based on cycle averages of the CAL-based delta ranges. Figure 3-5 shows the set of cycle averages of the combined height delta ranges with NO temperature correction applied, and these values are printed in Table 3-1. These are the same values that are available from our TOPEX web site at http://topex.wff.nasa.gov/docs/RangeStabUpdate.html, and that site is updated every month or so. The table at the web site also has the delta ranges which are temperature corrected for T_u using the correction developed for Side A. It was a mistake to continue using the Side A correction for the Side B data on the web site, and that will soon be corrected. The simple rule for Side B is to use the delta range that has NO temperature correction.

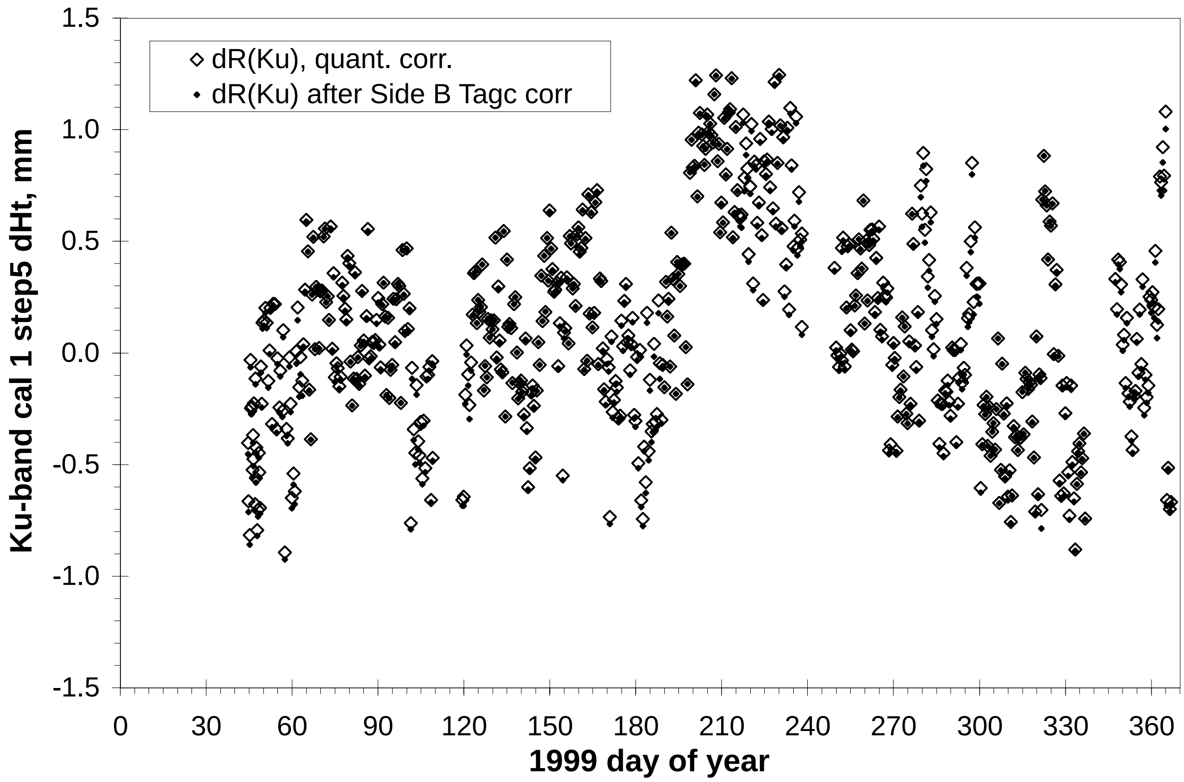

Figure 3-2 Ku-Band Cal 1 Step 5 Delta Height vs. Time for Side B data, Cycles 236-268

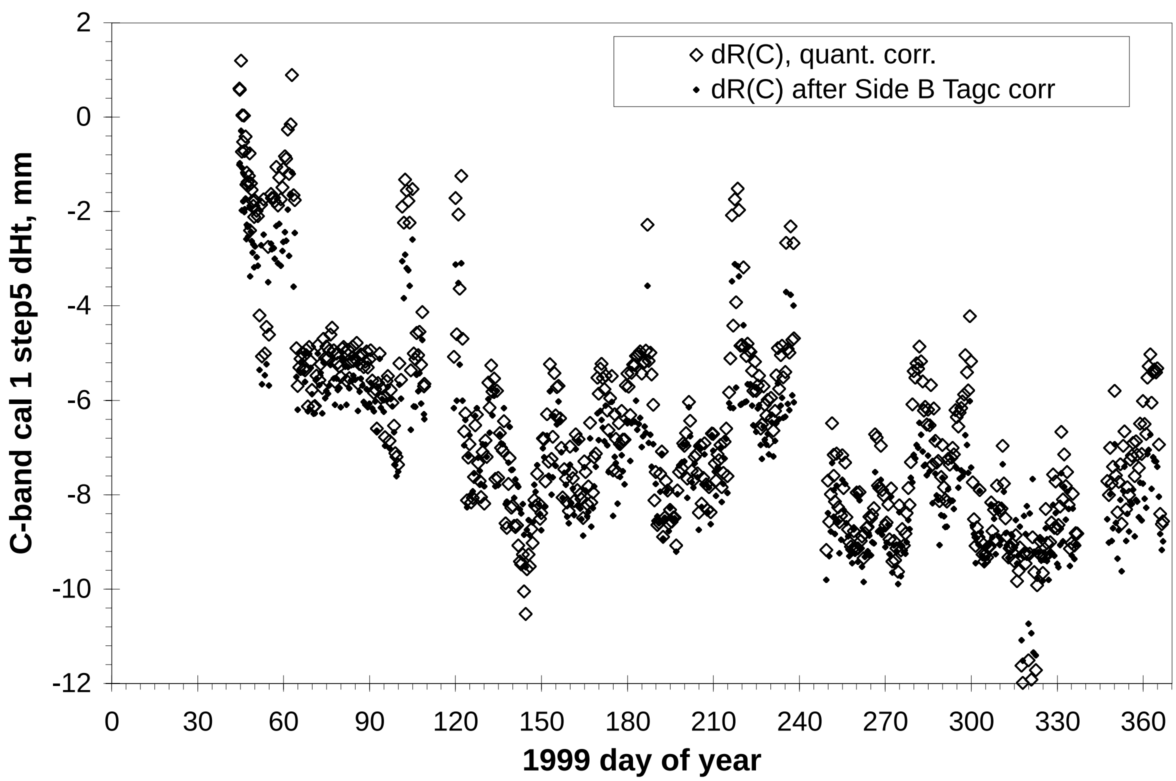

Figure 3-3 C-Band Cal 1 Step 5 Delta Height vs. Time for Side B Data, Cycles 236-268

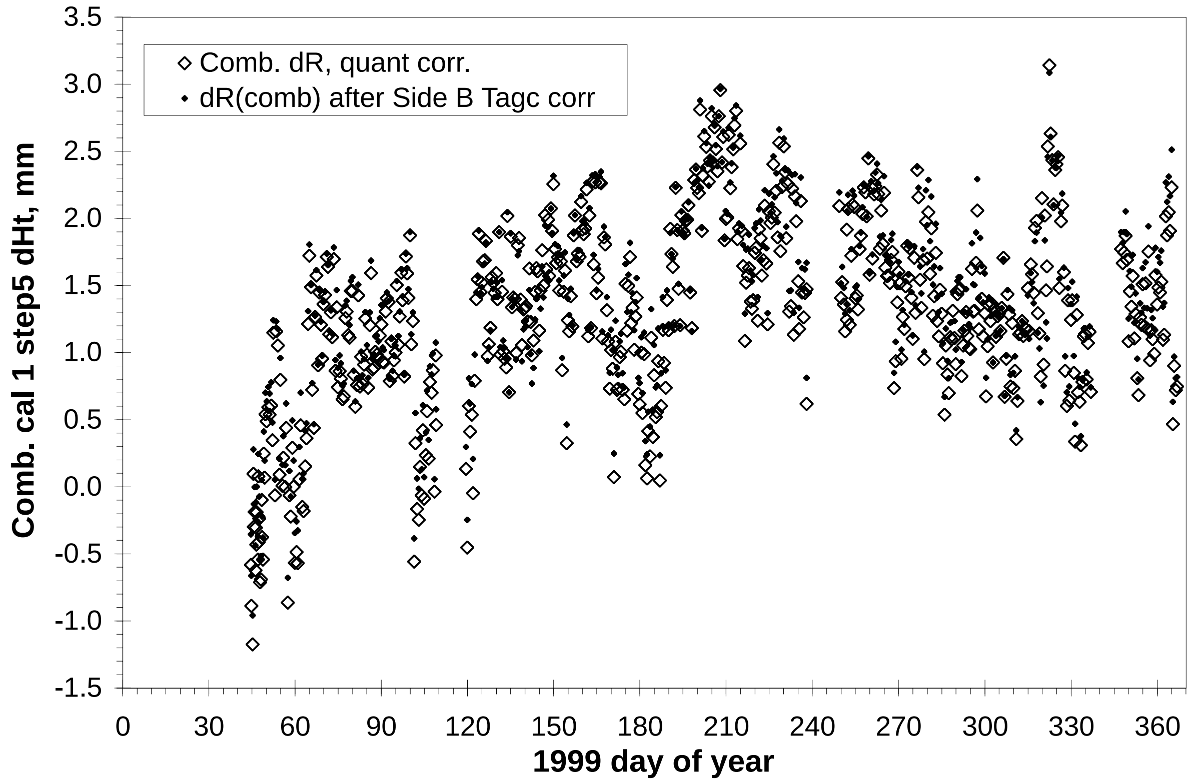

Figure 3-4 Ku & C Combined Cal 1 Step 5 Delta Height vs. Time for Side B Data, Cycles 236-268

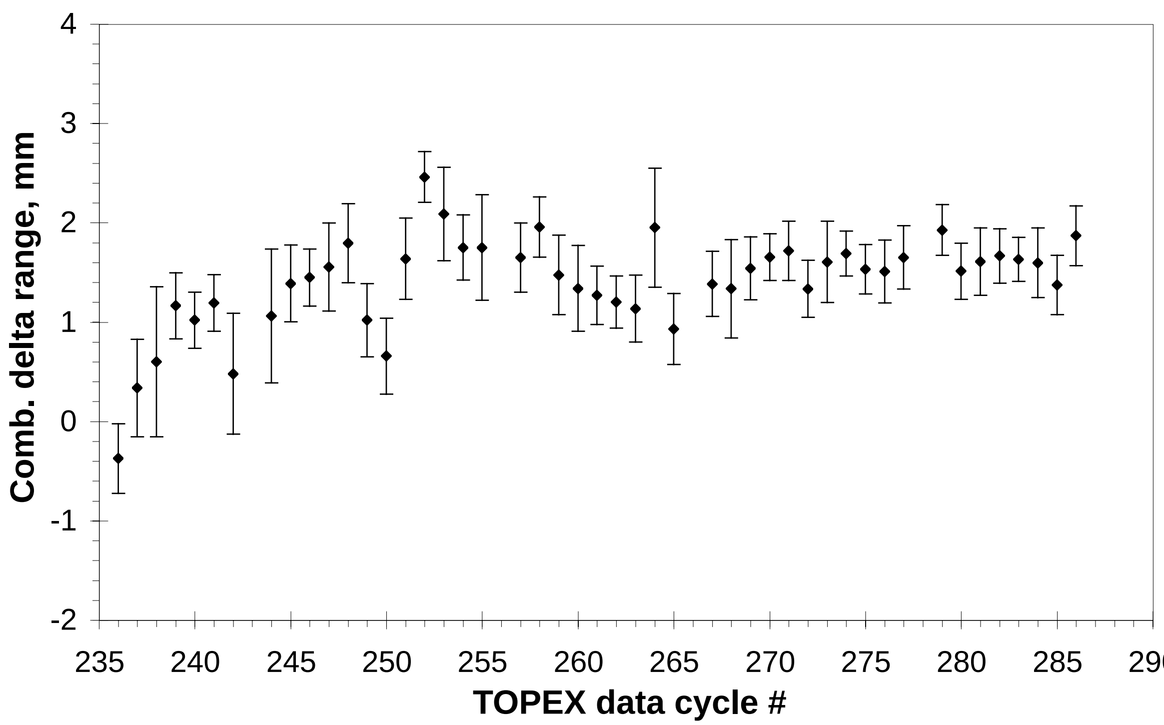

Figure 3-5 Side B Combined (Ku & C) Delta Range vs. Cycle NOT Corrected for Temperature

To correct the GDR range data for the range calibration drift, one would use

Corrected Range = GDR range - dR_av_N,

where dR_av_N is the cycle-average delta combined range value of Table 3-1 (as plot-

Cycle	Count	Mean dR(comb), no Tagc corr, mm	Std dev dR(comb), no Tagc corr, mm
236	21	-0.373	0.351
237	21	+0.336	0.490
238	20	+0.599	0.755
239	19	+1.163	0.333
240	20	+1.019	0.284
241	20	+1.191	0.284
242	21	+0.480	0.609
244	20	+1.062	0.673
245	19	+1.388	0.386
246	20	+1.448	0.288
247	20	+1.554	0.445
248	20	+1.793	0.398
249	20	+1.018	0.368
250	20	+0.657	0.383
251	19	+1.637	0.408
252	19	+2.460	0.256
253	20	+2.088	0.472
254	22	+1.749	0.328
255	21	+1.749	0.530
257	18	+1.649	0.346
258	20	+1.956	0.304
259	20	+1.473	0.400
260	20	+1.339	0.431
261	20	+1.269	0.292
262	20	+1.201	0.264
263	19	+1.135	0.338
264	21	+1.950	0.599
265	20	+0.929	0.356
267	20	+1.383	0.327
268	20	+1.335	0.494

Table 3-1 TOPEX Range Bias Changes Based on Calibration Mode 1 Step 5

ted in Figure 3-5). Note that the delta ranges are all given relative to a constant but arbitrary range offset, so this correction will provide only a relative range drift correction. The corresponding expression for correcting the GDR sea surface height (SSH) is

Corrected SSH= GDR SSH + dR_av_N.

3.2 AGC/Sigma Naught

The following sigma-naught discussion is restricted to TOPEX Side B operation in 1999. As noted in Section 3.1, previous years' assessment updates have supplied cumulative results for Side A from launch to the end of the assessment update period, but Side B is effectively a new altimeter and this year's assessment update will start with the Side B turn-on on 1999 day 040, early in TOPEX data cycle 236.

For an over-ocean radar altimeter the received backscattered power is, after suitable correction for off-nadir angle, proportional to the ocean's radar backscattering cross section which is usually designated as $F\sigma^0$ but referred to here as sigma-naught (or occasionally as sigma0) for typographical convenience. The altimeter's received power is indicated by the AGC, the receiver's "automatic gain control voltage" (although this is a misnomer as the AGC is calibrated in power (dB) terms, not in voltage). As the altimeter ages, its transmitted power tends to drift slowly (usually downward) by a few dB, and its receiver characteristics can also drift slowly. It is necessary to account for these drifts in power estimation when calculating sigma-naught estimates from the altimeter data.

In the TOPEX ground data processing for the intermediate geophysical data record (IGDR,) there is a sigma-naught calibration table which, for each TOPEX data cycle, contains an additive correction for the Ku-band sigma-naught and another additive correction for the C-band sigma-naught. WFF supplies values for this sigma-naught table which is referred to as the Cal Table in the following. The Cal Table values correct the TOPEX sigma-naught for the effects of the drifts in the altimeter's power estimation. The power estimation drifts are slow enough that the Cal Table values are constant for several cycles, and Cal Table changes are made only on cycle boundaries.

3.2.1 Processing of Calibration Mode Results and Global Sigma-Naught Averages

As part of our continuing TOPEX support, we do daily quick-look processing of all TOPEX altimeter data for performance monitoring, providing performance summaries for the engineering and science data. The daily processing results are used to update a launch-to-date engineering database. Also, data from the two daily calibration modes are processed and the results used to update a WFF launch-to-date calibration database. (See the calibration mode discussion in Section 2.3.) We also process the intermediate geophysical data record (IGDR) data as they become available for network access, normally several days after the altimeter acquires the data. The IGDR data are processed for altimeter performance, and 1-minute summary records are produced and are added to a WFF launch-to-date IGDR database. When the final geophysical record (GDR) data become available, they replace the IGDR data already in our database. There is no difference, however, between sigma-naught data on the IGDR and the GDR, because no further sigma-naught corrections are made in going from the IGDR to the GDR.

We have been very concerned about contamination of the data by what we have come to call "sigma-naught blooms", regions of over-ocean altimeter data characterized by unusually high apparent sigma-naught values accompanied by unusual altimeter waveform shapes. Generally the Ku-and the C-band sigma-naught show the same behavior in a bloom region. Such blooms in the TOPEX data can persist for several tens of seconds, and the waveforms in a bloom region generally have too rapid a plateau decay. Many of these waveforms are too sharply peaked (“specular”), indicating a breakdown in the general incoherent scattering theory used to characterize rough surface scattering. The sigma-naught blooms exist in perhaps 5% of all TOPEX over-ocean data (there is additional sigma-naught bloom information on our web site at http://topex.wff.nasa.gov/blooms/blooms.html). For input to our GDR database 1-minute averages, we require all the available altimeter flags to show normal tracking and the land/water flag to show deep water. When the data are extracted from this database for the sigma-naught calibration, all records are rejected that have Ku-band sigma-naught estimates of 16 dB or greater or that have waveform-estimated attitude angles of 0.12 degrees or greater; these criteria effectively delete the majority of the sigma-naught blooms.

Our investigation of possible drifts in sigma-naught estimation requires examination of possible time trends in the sigma-naught values before the Cal Table corrections are applied. These “uncorrected” sigma-naught values are referred to as sigma-naught_uncorr. Since our data come from the GDR (or IGDR), we need to know what Cal Table values have been already applied to the GDR (or IGDR) data in order to “undo” these corrections.

3.2.2 History of Cal Table Values Used in GDR Production

There have been three Cal Table adjustments during the 1999 TOPEX Side B operation. There exists no single summary of exactly when each of the Cal Table changes was implemented in the TOPEX ground processing, so we will try to provide that summary here. Each time that the Cal Table contents are changed in the TOPEX ground data processing at JPL, there are at least these three items created within the Mission Operations System (MOS):

- The MOS Change Request Form (the MCR) bears an origination date, describes the change to be made and the desired operational date for the implementation of the change, and also has the date when the MCR was approved (by a change control board at JPL).
- The Parameter File is the text file to be actually used in the data processing and containing the Cal Table values for each cycle.
- The File Release Form contains the Parameter File creation date, the release approval date, and the date at which file execution is to begin.

The MCR Form is usually accompanied by other supporting information from WFF describing why the change is being requested. In Table 3-2, we have summarized information from copies of the sigma-naught-related MCRs and File Release Forms relevant to the re-released GDRs (and the MGDR-Bs). Columns 1 to 3 of Table 3-2 are transcribed from the MCR Forms, columns 4 and 5 from the File Release Forms, and column 6 contains a brief indication of what change the MCR made and why. Column 7 of Table 3-2 indicates which of the TOPEX GDRs were governed by each MCR.

Table 3-2 TOPEX MCR Information Summary

From MCR Form			From File Release Form		Additional Information	
(1) MCR #	(2) MCR Origination Date	(3) Comments on MCR Form	(4) File Creation Date	(5) Release Approval Date	(6) Comments on MCR Actions and Reasons	(7) Cycles Distributed Under This MCR
690	99/05/26 1999-146	After indicated parameter & constant changes, produce IGDRs and GDRs from all Alt-B data to date	99/05/25 1999-145	99/05/28	After initial Cal/Val activity, set constant Ku and C biases with values chosen to make smooth connection to Side A results.	236 - 247
692	99/06/16 1999-167	see attached request memo from Callahan asking that cycle 248 be reprocessed	9/06/17 1999-168	99/06/17	C-band has a trend estimated from first 12 cycles (1st C-band change is at cycle 242), Ku-band has zero trend.	248 - 258
701	2000/01/10 2000-010	Begin use for cycle 259.	2000/01/13 2000-013	2000/01/13	Put in linear trend for Ku, and changed linear trend for C. Still assuming single linear trends from cycle 236 for Ku and for C.	259 - 276

In TOPEX Side A there were indications that the time trend of the CAL-1 AGC differed from the time trend of the over-ocean cycle-averaged sigma-naught in both the Ku- and the C-band systems. We were forced to use the time trend of the over-ocean sigma-naught cycle-averages to produce the sigma-naught Cal Table entries. We tried to make these corrections only for relatively long periods of time, avoiding responding to cycle-to-cycle noise. Correcting a noisy process by making trend projections is a frustrating activity at best, and the Side A Cal Table has several places where we failed to detect trend changes or failed to correct our trend projections soon enough. After TOPEX was switched to its Side B in early February 1999, we described the entire Side A Cal Table history in “TOPEX sigma0 calibration table history for all Side A data”, G.S. Hayne and D.W. Hancock III, 27 July 1999, available at GOTOBUTTON BM_1_ http://topex.wff.nasa.gov/docs/Sigma0Cal_A_All.pdf. In that paper we produced our best estimates at what values the Cal Table should have included. This best estimate was obtained from a quadratic trend fit to the entire Side A set of over-ocean cycle-averages of sigma-naught.

When Side B was turned on, we continued to do as we had done for Side A. The initial Side B Cal Table entries were chosen so that there was no obvious discontinuity in over-ocean sigma-naught from Side A to Side B; these initial values were decided upon by the Side B Cal/Val team with inputs from JPL as well as WFF. These initial Cal Table values were held constant for a while until trends started to appear. During all of year 1999, we were assuming that there would be time trends from initial Side B turn-on, and based on Side A behavior we assumed that the trends would be adequately described as linear with time for at least the first two years of Side B operation.

The Side B C-band Cal Table values were changed beginning with cycle 248 to correct for an apparent downward trend in the C-band over-ocean sigma-naught. No corrections were made to the Side B Ku-band Cal Table until cycle 259 when it became clear that there was an upward trend in the Ku-band over-ocean sigma-naught. Both the Ku- and the C-band Cal Table values were produced by assuming a linear trend in the over-ocean sigma-naught. The Ku-band system was particularly surprising in showing an increase in over-ocean sigma-naught estimates before correction.

Table 3-3 summarizes the Side B Cal Table values used in the distributed Side B data products for year 1999. Column 1 of Table 3-3 is the data cycle number, and columns 4 and 5 give the Ku- and C-band Cal Table values which were used in producing the TOPEX GDR data product. Columns 6 and 7 provide hindcast values based on a two

Table 3-3 TOPEX Cal Table Entries for Distributed GDRs

			Cal Table Values Used in Distributed Data		Best Cal Table Values, 2-segment fit to CAL-1		Adjustment for Already-Distributed Data	
(1) TOPEX Cycle	(2) Applicable MCR #	(3) Which Altimeter	(4) Ku Cal Table, dB	(5) C Cal Table, dB	(6) Best Ku Cal, dB	(7) Best C Cal, dB	(8) Ku Adjust, dB	(9) C Adjust, dB
236	690	NRA_sideB	+0.45	+0.55	+0.46	+0.53	+0.010	-0.019
237	690	NRA_sideB	+0.45	+0.55	+0.46	+0.54	+0.008	-0.014
238	690	NRA_sideB	+0.45	+0.55	+0.46	+0.54	+0.005	-0.009
239	690	NRA_sideB	+0.45	+0.55	+0.45	+0.55	+0.003	-0.005
240	690	NRA_sideB	+0.45	+0.55	+0.45	+0.55	+0.000	+0.000
241	690	NRA_sideB	+0.45	+0.55	+0.45	+0.55	-0.003	+0.005
242	690	NRA_sideB	+0.45	+0.55	+0.44	+0.56	-0.005	+0.009
243	690	SSALT						
244	690	NRA_sideB	+0.45	+0.55	+0.44	+0.57	-0.010	+0.019
245	690	NRA_sideB	+0.45	+0.55	+0.44	+0.57	-0.013	+0.024
246	690	NRA_sideB	+0.45	+0.55	+0.43	+0.58	-0.015	+0.028
247	690	NRA_sideB	+0.45	+0.55	+0.43	+0.58	-0.018	+0.033
248	692	NRA_sideB	+0.45	+0.61	+0.43	+0.59	-0.021	-0.022
249	692	NRA_sideB	+0.45	+0.61	+0.43	+0.59	-0.023	-0.018
250	692	NRA_sideB	+0.45	+0.61	+0.42	+0.60	-0.026	-0.013
251	692	NRA_sideB	+0.45	+0.61	+0.42	+0.60	-0.028	-0.008

Table 3-3 TOPEX Cal Table Entries for Distributed GDRs (Continued)

			Cal Table Values Used in Distributed Data		Best Cal Table Values, 2-segment fit to CAL-1		Adjustment for Already-Distributed Data	
(1) TOPEX Cycle	(2) Applicable MCR #	(3) Which Altimeter	(4) Ku Cal Table, dB	(5) C Cal Table, dB	(6) Best Ku Cal, dB	(7) Best C Cal, dB	(8) Ku Adjust, dB	(9) C Adjust, dB
252	692	NRA_sideB	+0.45	+0.61	+0.42	+0.61	-0.031	-0.003
253	692	NRA_sideB	+0.45	+0.64	+0.42	+0.61	-0.033	-0.029
254	692	NRA_sideB	+0.45	+0.64	+0.41	+0.62	-0.036	-0.024
255	692	NRA_sideB	+0.45	+0.64	+0.41	+0.62	-0.039	-0.019
256	692	SSALT						
257	692	NRA_sideB	+0.45	+0.64	+0.27	+0.55	-0.181	-0.087
258	692	NRA_sideB	+0.45	+0.64	+0.27	+0.55	-0.184	-0.086
259	701	NRA_sideB	+0.27	+0.64	+0.26	+0.56	-0.006	-0.084
260	701	NRA_sideB	+0.27	+0.64	+0.26	+0.56	-0.008	-0.082
261	701	NRA_sideB	+0.27	+0.64	+0.26	+0.56	-0.010	-0.081
262	701	NRA_sideB	+0.24	+0.64	+0.26	+0.56	+0.017	-0.079
263	701	NRA_sideB	+0.24	+0.67	+0.25	+0.56	+0.015	-0.108
264	701	NRA_sideB	+0.24	+0.67	+0.25	+0.56	+0.013	-0.106
265	701	NRA_sideB	+0.24	+0.67	+0.25	+0.57	+0.010	-0.105
266	701	SSALT						
267	701	NRA_sideB	+0.21	+0.67	+0.25	+0.57	+0.036	-0.102
268	701	NRA_sideB	+0.21	+0.67	+0.24	+0.57	+0.034	-0.100

segment fit (discussed in Section 3.2.4), and columns 8 and 9 list the differences between the forecast (columns 4 and 5) and the hindcast (columns 6 and 7).

3.2.3 Observed Trends in Calibration Mode and Sigma-Naught Cycle-Averages

Figure 3-6 summarizes the Side B Ku-band altimeter's CAL-1, CAL-2, transmit power monitor, and over-ocean sigma-naught cycle averages for cycles 236 - 284, and Figure 3-7 presents the corresponding information for the C-band altimeter. A small seasonal correction, derived from the entire set of Side A sigma-naught data, has been applied to the over-ocean sigma-naught averages. The Cal Table corrections have been removed from the over-ocean sigma-naught in these figures. In Figure 3-6 and Figure 3-7, the CAL-1 delta AGC trend is in quite good agreement with the over-ocean sigma-naught trend, suggesting that the CAL-1 AGC change would provide an

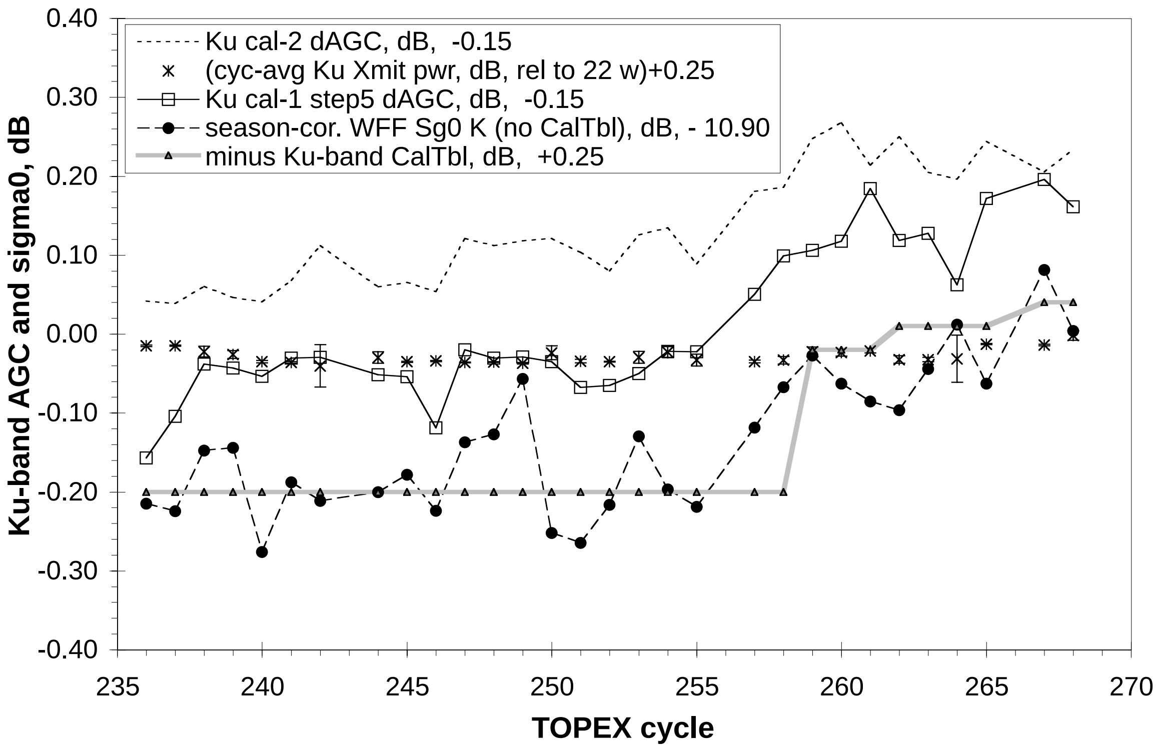

Figure 3-6 Ku Side B Cycle-Avg Cal-1 & Cal-2 Delta AGC, Sigma0 (Cal Table Corrections Removed)

adequate basis for the Side B Cal Table (unlike the Side A altimeter where the CAL-1 trend differed from the over-ocean sigma-naught trend).

Another effect visible in Figure 3-6 is an apparent step-change in both the Ku-band CAL-1 and the Ku-band over-ocean sigma-naught. This step occurred at cycle 256 which was a SSALT cycle during which a satellite safe hold occurred. A consequence of the safe hold was that the TOPEX altimeter was powered off during most of cycle 256; this was different from a normal SSALT cycle during which the TOPEX altimeter would have been powered but in its standby mode. We don't know the reason, but the TOPEX altimeter apparently behaved differently before and after this cycle 256 event. There is a visible step-change seen in Figure 3-6, and there was also a change in the Ku-band altimeter's track acquisition behavior in land-to-water transitions. Prior to cycle 256, there were occasional cases of the Ku-band altimeter's requiring several tens of seconds for acquisition, but after the cycle 256 safe hold the Ku-band land-to-water track transitions no longer showed the occasional anomalous long acquisition times. For whatever reason, the Side B altimeter behaved differently after the cycle 256 safe hold. The C-band altimeter Figure 3-7 shows less magnitude of effect than the Ku-band Figure 3-6, but there does appear to be a small C-band step change at cycle 256 in Figure 3-7.

3.2.4 CAL-1 Fitted Trends for Estimation of Cal Table Values

Based on Figure 3-6 and Figure 3-7, we decided to use the CAL-1 data as the entire basis for the Side B sigma-naught Cal Table. We further decided to fit straight line

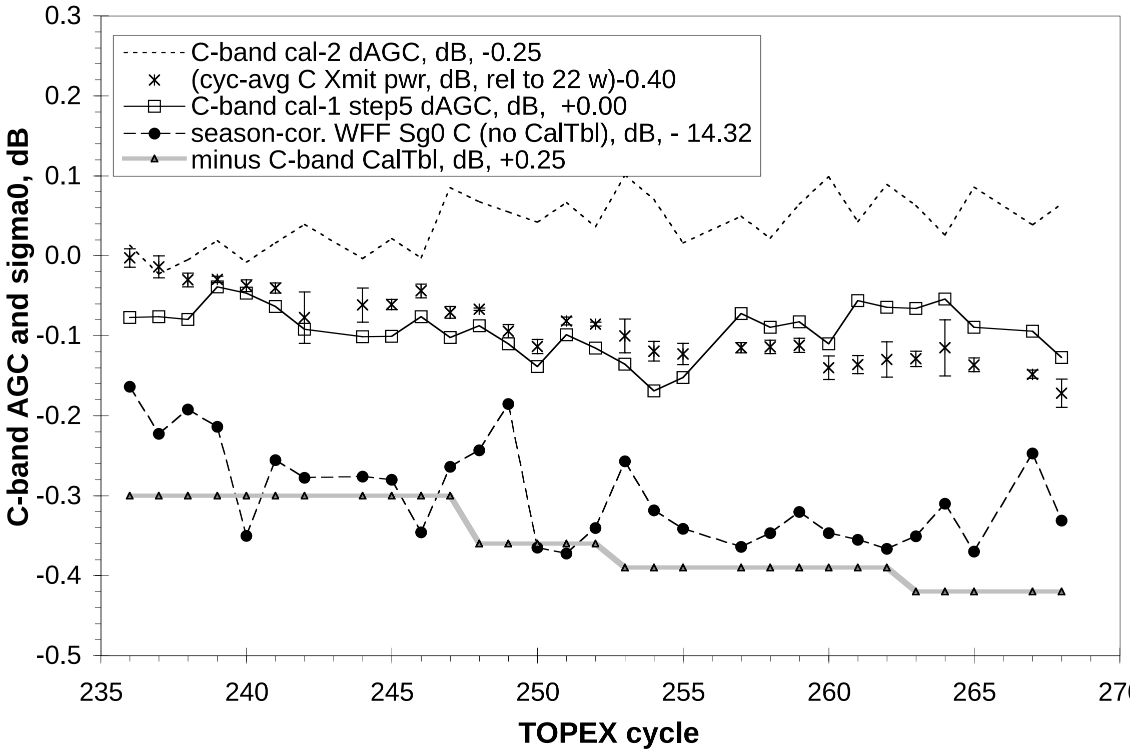

Figure 3-7 C-Band Side B Cyc-Avg Cal-1 & Cal-2 Delta AGC, Sigma0 (Cal Table Corrections Removed)

segments to the Side B CAL-1 data, with different slope and intercept values before and after cycle 256 to allow for a possible step change in altimeter characteristics. The step-change at cycle 256 becomes more obvious with an additional half year's data beyond that shown in Figure 3-6 and Figure 3-7. The line-segment fits discussed here were made using data through cycle 284 (which started on day 151 of year 2000), but only the year 1999 data are shown in this 1999 Update to the Engineering Assessment Report.

The result of the CAL-1 fits by discontinuous line segments is shown by Figure 3-8 for Ku-band and Figure 3-9 for C-band. The error bars shown in Figure 3-8 and Figure 3-9 are the estimated individual standard deviations of the 20 CAL-1 Step 5 results from which the cycle averages are formed. The (negative of) Figure 3-8 and Figure 3-9 fit data provide relative sigma-naught corrections, and it was arbitrarily decided to set the CAL-1-based corrections to zero at cycle 240; that is, we assumed that +0.45 dB was the correct Ku-band Cal Table value and that +0.55 dB was the correct C-band Cal Table value at cycle 240. This allows us to calculate the values given in columns 6 and 7 of Table 3-3; these are our current best estimate of the values which should have been in the Cal Table. Figure 3-10 shows the relationship of the Ku-band Side B CAL-1 fitted line segments to the Cal Table values used in the 1999 distributed TOPEX data, and Figure 3-11 shows the same thing for C-band.

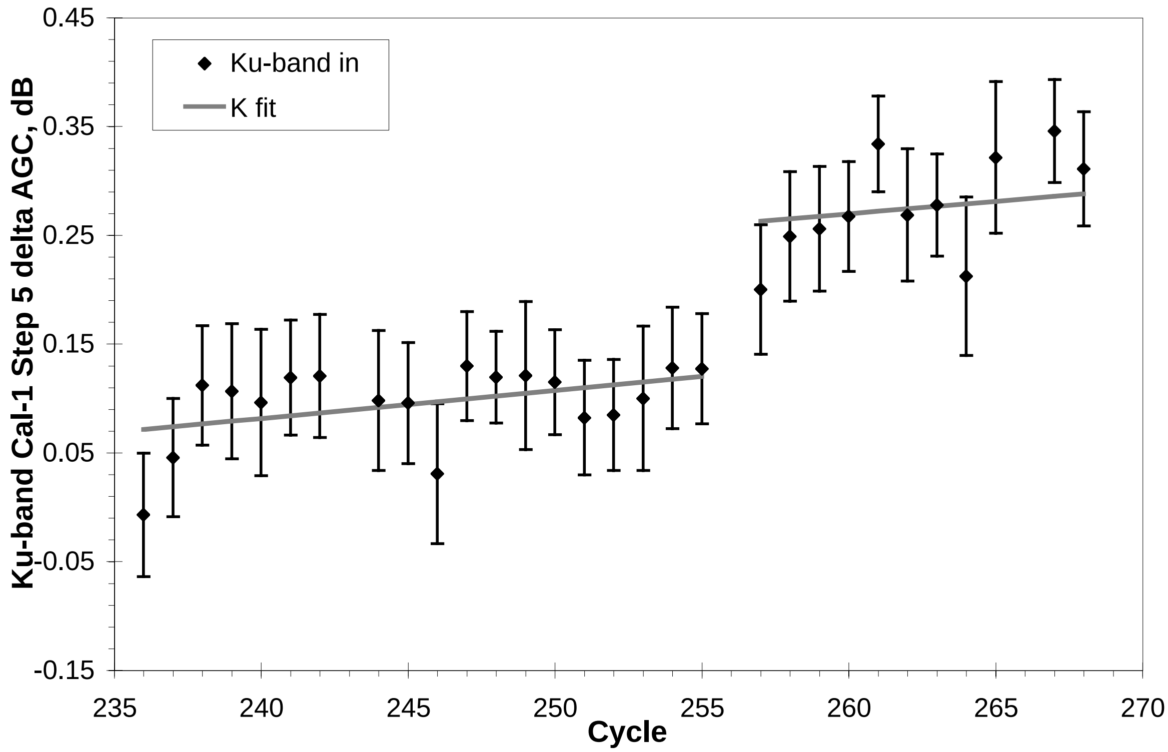

Figure 3-8 TOPEX Side B Ku-Band Cal Mode 1 Delta AGC vs. Cycle fitted by 2 discontinuous straight-line segments, changing at cycle 256

In practical terms we can find the "delta correction" values to be added to the current GDR sigma-naught values to produce those sigma-naught values which would have been obtained if the ground processing had used column 6 and 7 values of Table 3-3 instead of column 4 and 5. These delta correction values are given in columns 8 and 9 of Table 3-3, and are plotted in Figure 3-12. Figure 3-12 shows that the Ku-band sigma-naught values for cycles 257 and 258 need the greatest additional adjustment. This is not surprising, given that no change in the Ku-band Cal Table was made from the cycle 236 start of Side B operation until cycle 259.

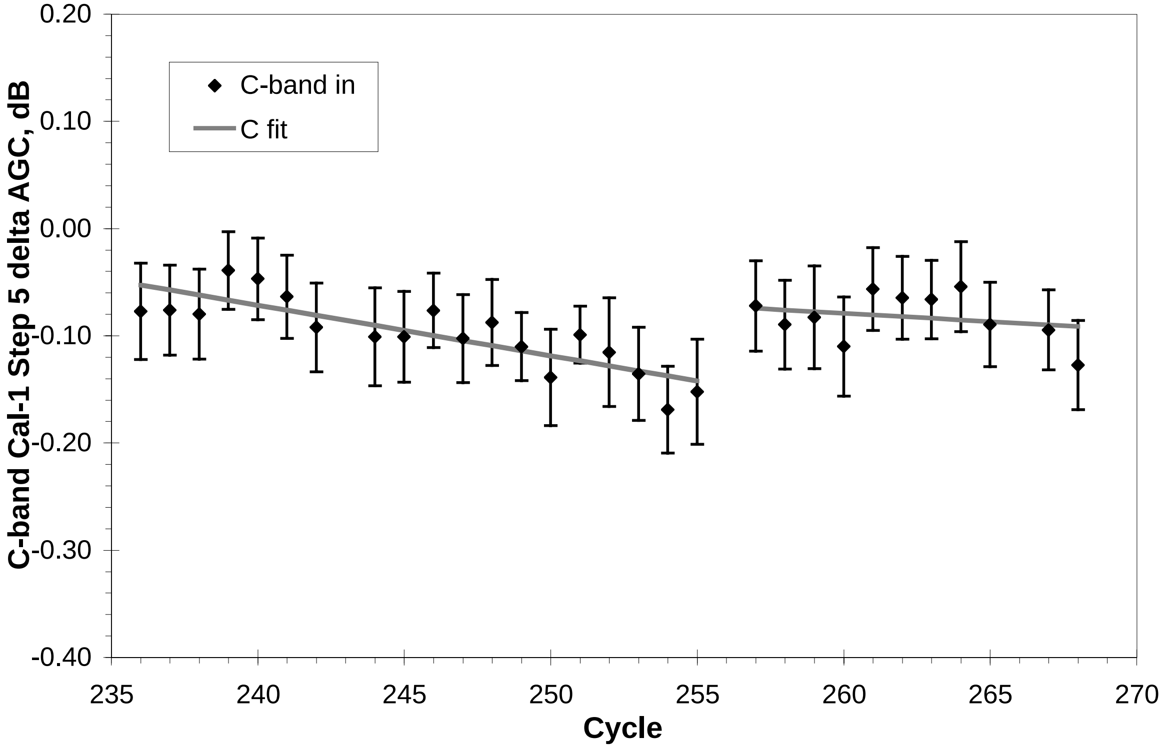

Figure 3-9 TOPEX Side B C-Band Cal Mode 1 Delta AGC vs. Cycle fitted by 2 discontinuous straight-line segments, changing at cycle 256

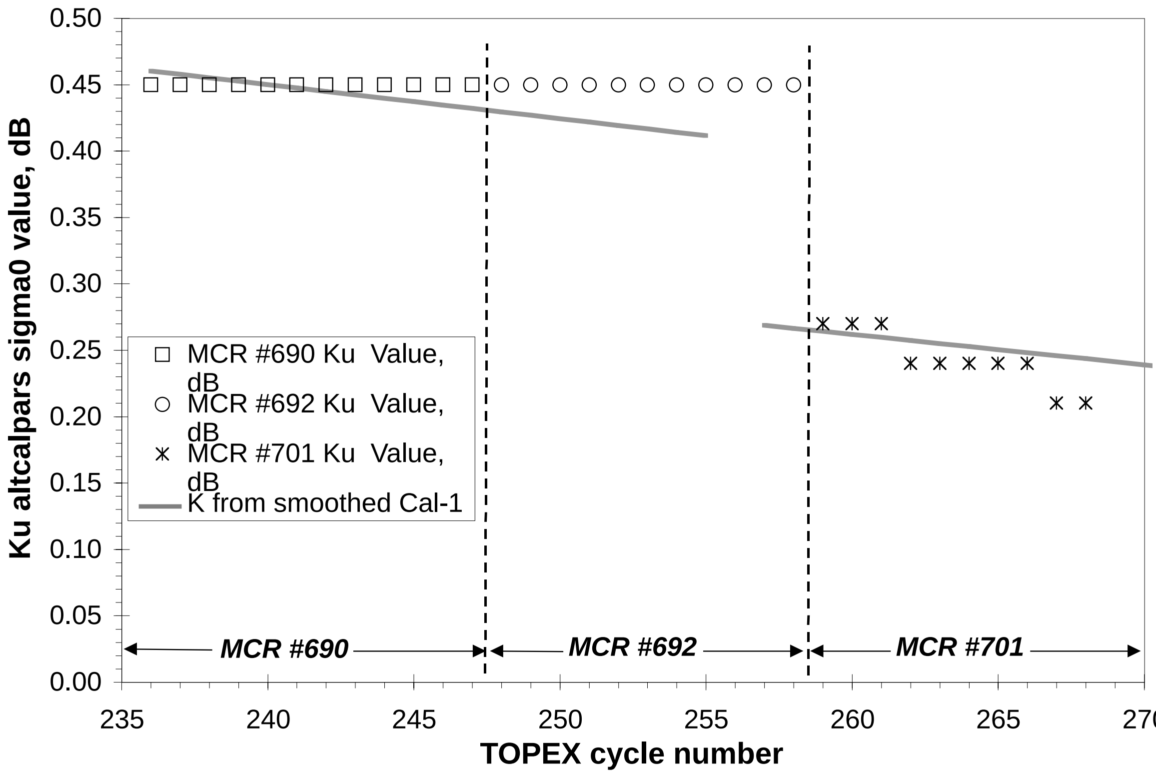

Figure 3-10 TOPEX Side B Ku-Band Sigma0 Calibration Table Value

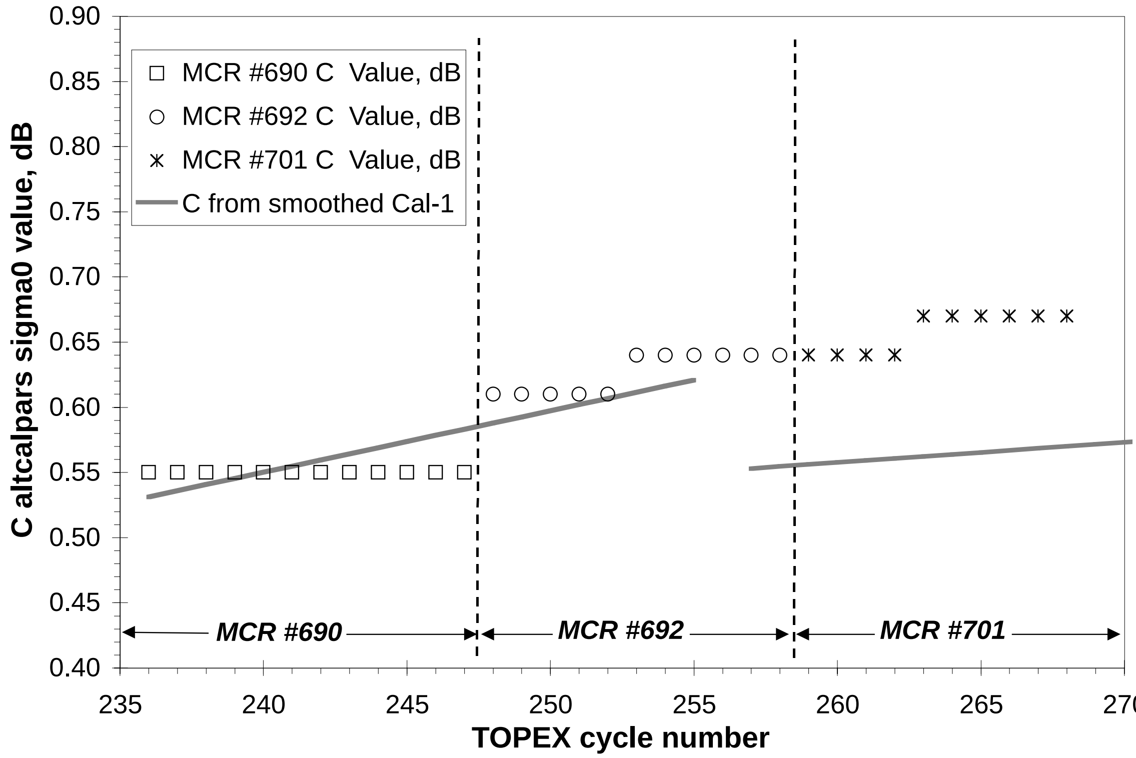

Figure 3-11 TOPEX Side B C-Band Sigma0 Calibration Table Value

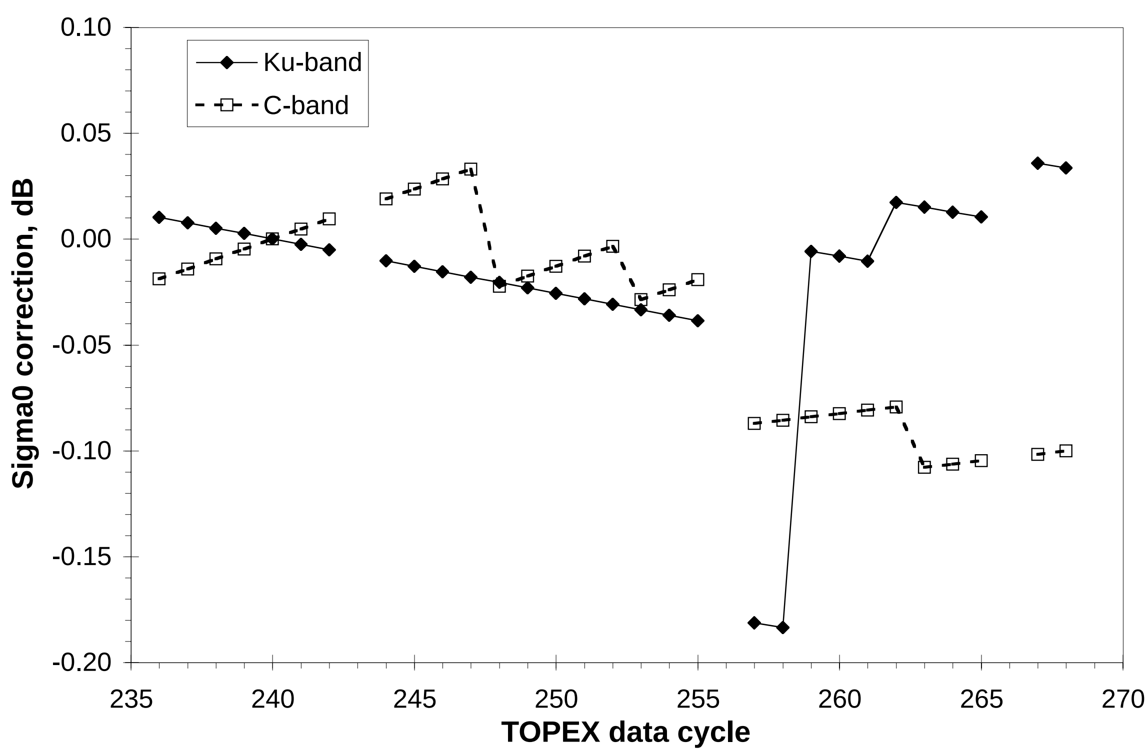

Figure 3-12 Correction for Already-Distributed TOPEX Side B Data to adjust all cycles by 2-segment fit to CAL-1

3.3 Side B Point Target Response

Changes in the TOPEX Side A altimeter became apparent around the middle of 1998. The first symptoms of the changes were an increase in the altimeter's SWH estimates and an increase in the range rms. Subsequent investigation revealed apparent changes in the altimeter's point target response (PTR); these changes were shown by the waveform data in the altimeter's Calibration Mode 1 (CAL-1). The Side A PTR changes were the reason that the altimeter was switched to its Side B in February 1999 near the start of cycle 236.

The normal TOPEX CAL-1 has executed at least twice daily throughout the entire TOPEX operation. In CAL-1 a portion of the transmitted signal is fed back into the altimeter receiver through a special calibration attenuator and the altimeter tracks this transmitted signal using a special tracking algorithm. During the preflight testing a special calibration mode sweep test (the CalSweep) had been developed in which the altimeter did not automatically track the PTR but instead the AGC level was frozen at a preset level and the altimeter's fine-height word was incremented through its entire range (equivalent to 8 waveform sample positions). The CalSweep waveforms can be processed to give a "fine-grained" look at the PTR. After the Side A overestimates of SWH became apparent, a software patch was uploaded to TOPEX to allow the CalSweep to be executed on-orbit. The CalSweep was executed approximately monthly from mid-1998 through the end of the Side A operation. Last year's Engineering Assessment Update contains a more detailed discussion of the Side A PTR observation by CAL-1 and CalSweep, and the consequences of the Side A PTR change.

The CalSweep has continued to be executed about once a month for the entire time of Side B operation. Figure 3-13 shows the comparison of the first and last Side B Ku-band CalSweep results in 1999, and Figure 3-14 shows the same comparison for the 1999 Side B C-band. As a reference, the theoretical model for the PTR is shown by the pure sinc^2 plotted in Figure 3-13 and Figure 3-14. Only the central lobe and the first five sidelobes are shown in these figures. To within the accuracy and repeatability of the CalSweep, there has been no significant change in the Side B CalSweep results over all of year 1999.

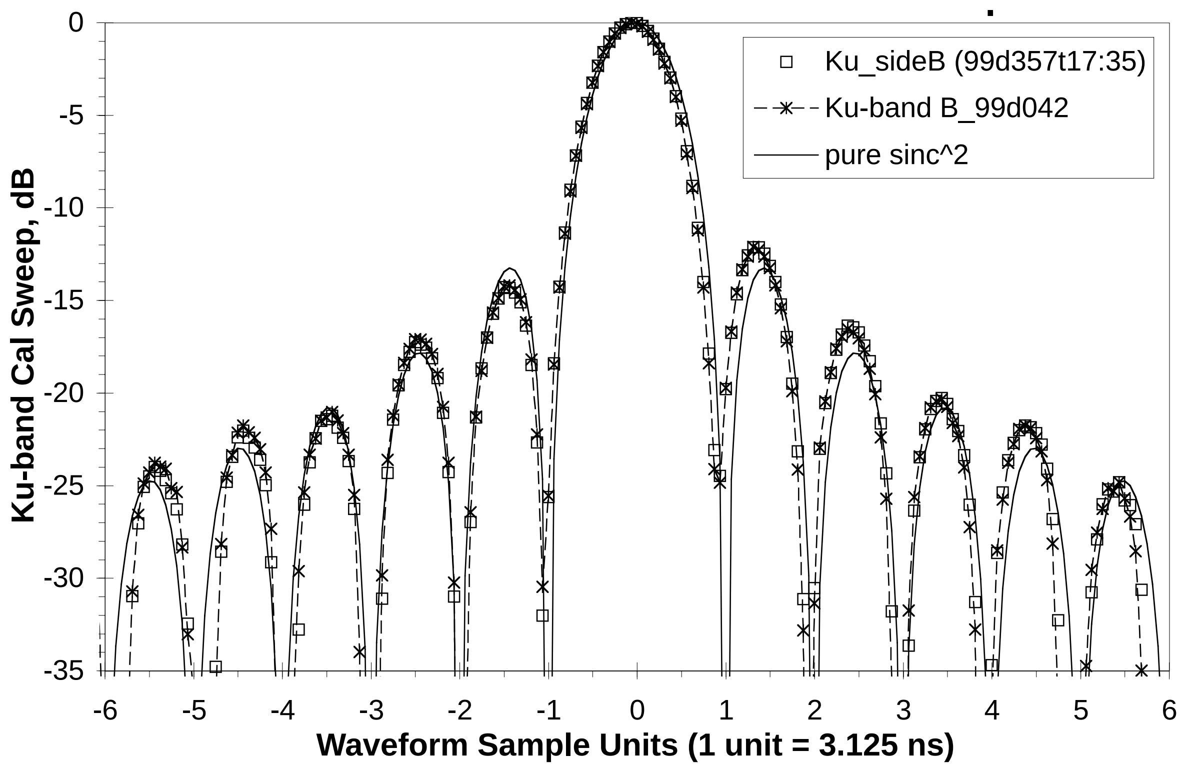

Figure 3-13 Side B First and Last 1999 Ku-Band Cal Sweeps

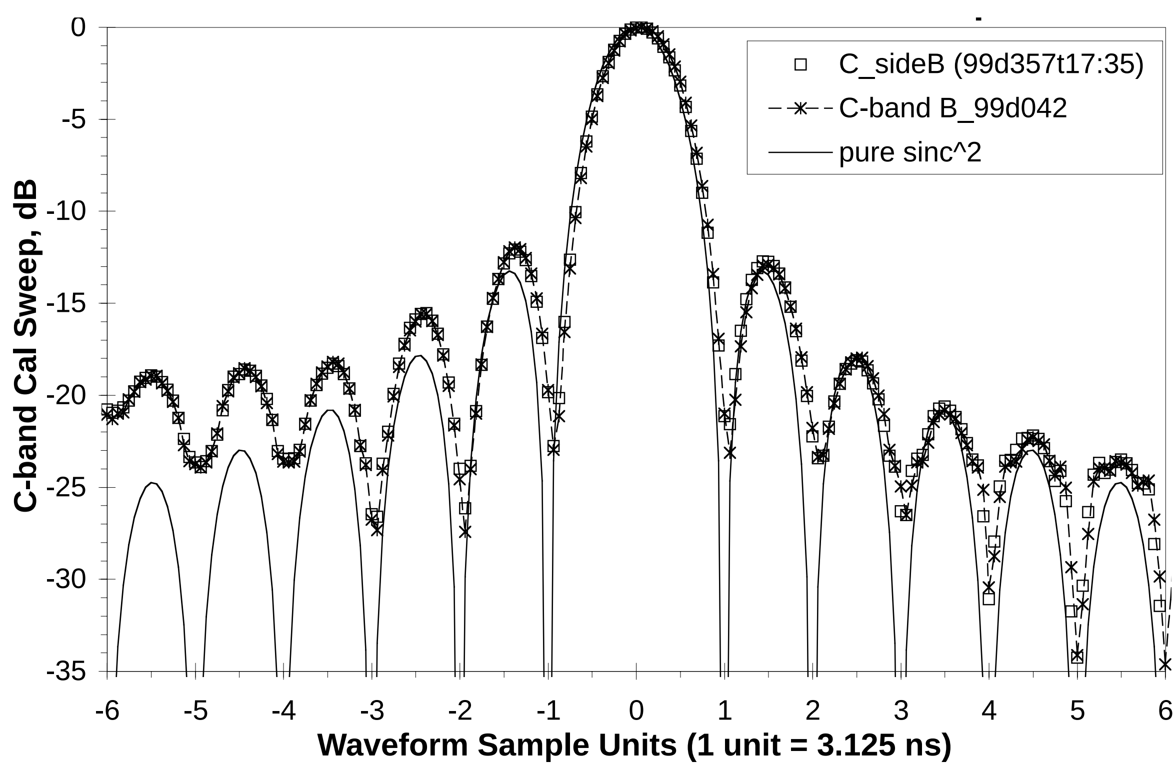

Figure 3-14 Side B First and Last 1999 C-Band Cal Sweeps

Section 4

Engineering Assessment Synopsis

4.1 Performance Overview

Side B of the NASA Radar Altimeter was turned on, for the first time in space, on February 11, 1999. This followed six-and-a-half years of very successful on-orbit operations by Side A. Side A was turned off due to its Point Target Response (PTR) having changed slightly over time, affecting measurement consistency. Side B is now the operational altimeter; however, Side A could be turned back on if needed.

Side A performance significantly surpassed all its pre-launch specifications, including its length of service; its design lifetime was three years, with a goal of five years. The primary pre-launch specification for the altimeter was to monitor and maintain range calibration to the +1.5 cm level. Based on the published results of TOPEX science investigators, unprecedented range measurement accuracy has been achieved with this altimeter data set. With our analysis techniques, we believe that we have achieved range calibration (i.e., internal range consistency) at the one-centimeter level, and have made meaningful inroads towards the sub-centimeter level.

Based on our performance analysis and based on the reports of science investigators, Side B is performing as well as, or perhaps even better than, Side A.

We are continuing our NASA Radar Altimeter performance assessment on a daily basis, now with Side B, and are continuing to develop improved analysis techniques. Our performance assessment techniques are relevant not only for the NASA Radar Altimeter, but are very applicable to other spaceborne altimeters as well.

Section 5

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